THE

AËRONAUTICAL JOURNAL.

(FOUNDED 1897 in succession to the ANNUAL REPORTS).

THE ORGAN OF THE ROYAL AËRONAUTICAL SOCIETY.

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Edited for the Council by W. BARNARD FARADAY, LL.B., F.S.S., Barrister-at-Law

All communications should be addressed to the Editor.

No. 99. MARCH, 1919. VOL. XXIII.

Notices of the Royal Aëronautical Society.

At a meeting held on Friday, March 28th, the Council of the Royal Aëronautical Society decided that:—

Pilots and all other persons now or lately employed in Government service in connection with aeronautics are strongly advised not to pay registration or other fees to any employment or other agency of a similar character without making the fullest possible inquiry into the bona-fides of such agencies.

ANNUAL GENERAL MEETING.

The 54th Annual General Meeting of the Royal Aëronautical Society was held in the Offices of the Society, 7, Albemarle Street, London, on Wednesday, April 2nd, 1919. The Chairman of the Society, Major-General R. M. Ruck, C.B., C.M.G., R.E., was in the chair, and was supported by the following members of Council:—Major A. R. Low, Dr. T. E. Stanton, Mr. L. Bairstow, Lieutenant-Colonel T. R. Cave-Browne-Cave, Lieutenant-Colonel A. Ogilvie and Sir Mackenzie Chalmers, and by Mr. Patrick Alexander, Mr. Chas. Bright, and other voters of the Society.

The Secretary read the notice convening the meeting.

Miss Hilda Hudson, Mr. W. F. Field and Mr. R. L. Ragg were appointed scrutineers of the ballot for the elections to the Council.

The CHAIRMAN, in presenting the Annual Report and Balance Sheet of the Council, said:—

I have little to add to the Report of the Council which has been presented to you, but as this is the last occasion on which I shall have the honour of addressing the annual meeting from the chair, I should like to enlarge upon a few points in connection with the Society.

I have first to suggest that the gracious recognition of the work of the Society by His Majesty is, I am sure, deeply appreciated by all.

I have next to congratulate the members that we have passed from a state of war to one of peace, but the war has certainly given rise to a very rapid development in aviation and has, therefore, very distinctly benefited our Society;

the experience gained is now being turned with the greatest advantage to commercial enterprise.

I have further to remark that the continued support of the Society by the authorities must be equally gratifying to the members and the Council. The progress of the Society speaks for itself.

When I first took the chair, seven years ago, it was as much as we could do to keep going, and as far as finance was concerned, the Society had been supported largely by the generosity of one of its members, Mr. Patrick Alexander. There was one great asset, however, for there was plenty of energy and plenty of talent amongst the members and they thoroughly believed in the ultimate future of aerial navigation.

Sometimes I think that we do not sufficiently appreciate the efforts of the pioneers in this movement. They fought most strenuously against ignorance, prejudice, and even ridicule, but the ultimate success is due very largely to some of their efforts. At the time I have just referred to the membership of the Society was about 200 with an income of little over £250. The report which is in your hands shows that the membership has now been increased nearly sixfold and the income more than tenfold; these figures are still rapidly increasing. We have, as you will see, a sum of over £2,500 in hand in cash as against £1,400 the year before and £700 in 1916, while the income last year approached £3,000.

Even more satisfactory is the development of the Society in prestige, position and useful activities. This is also indicated in the report and in the last list of members. I refer more particularly to the valuable series of lectures which have been delivered and the work of the Technical Terms Committee, presided over very ably by Colonel O'Gorman. The discussions after the lectures have been very satisfactory, with few exceptions, and the attendance everything which could be desired. I was particularly struck by the attendance at Colonel Cave's lecture a short time ago.

I should like to emphasise what I believe to be the extreme importance of continuing to develop the Society on its technical and educational side as well as its more purely scientific aspect. The two subjects are, to my mind, inextricably bound up together if the Society is to carry out its *rôle* to the greatest possible national advantage.

Personally, I have been very much impressed by the wisdom of those who founded our Society under the presidency of the Duke of Argyll in 1866, that is to say, that from the first it has been composed of men of science, of distinguished engineers, and also of others, many of them prominent men, who, though not possessing any special scientific or technical qualifications, have been keenly interested in the development of flying.

I sincerely hope that this constitution, which I believe is unique, will not be changed, as the association of these different classes is, I believe, invaluable in securing progress on the right lines. We have had numerous discussions on this subject and also regarding the qualifications which are desirable for candidates for the technical grades and we have invited distinguished members of other societies and institutions to take part in these discussions; the result has been that we have adhered generally to our original constitution, but now that the Society has reached its present dimensions, and taking into consideration also the general advance in aeronautical knowledge, there should be no doubt some tightening up of the standards required.

Another subject I desire to refer to, namely, the desirability of proceeding rapidly with the formation of local branches of the Society in favourable neighbourhoods. Successful branches would, I think, not only benefit the Society, but would also be of national value, being likely to be of considerable assistance to the authorities in developing their scheme of aerial traffic. It will want a lot

of go put into it, and we ought to be able to do that locally. Local difficulties could be discussed and how to overcome them. We ought to organise it from headquarters and send down good lecturers.

I would also draw your attention to the Commemoration Entertainment which is proposed to take place in the summer. We want to celebrate our jubilee, the new title conferred upon the Society, and the fact that our membership has reached 1,000 and more. I hope that all members will do their utmost to make it a success.

It remains now only to thank those, including especially the Secretariat, past and present, who have assisted me so greatly in my work as chairman; in my opinion you could not have had a better and more representative Council—their advice, resource and energy have alone enabled me to carry out my duties, I hope in a satisfactory manner. There has been a great strain on everyone during the war and the Council are very busy men, but they have never failed me.

I think that, as stated in the Report, we can look forward with the utmost confidence to a great and prosperous future for the Society.

Dr. WALMSLEY: I have much pleasure in seconding the adoption of the Report and Balance Sheet, so ably proposed from the chair.

Mr. A. OGILVIE, C.B.E., said he could only concur in the statement made by the Chairman as to the satisfactory state of the Society and the very great improvements which had taken place.

He felt that he would have liked very much to have taken a larger share of the work, but unfortunately, owing to his work and other reasons during the year, he had not been able to do as much as he could have wished. He was sure that the same remark applied to several other members of Council. They felt, however, that in their Chairman they had someone who would do them credit, and he would like to put a few words in that sense. He thought the Society in being granted the title of "Royal" had made a big step forward. As regards the future, he personally felt that there was considerable scope for the work of the Society in the furtherance of civil aerial transport, and added:—"I do not know if I ought to say very much more, but I certainly think that the Air Ministry will want a certain amount of assistance from bodies of this sort, because if they do not get such assistance they certainly will not have the body of scientific and technical men's information behind them. I scarcely think they will have, in the future, everything in their hands as they have had during the war, at any rate to the same degree.

"I need scarcely add that I heartily congratulate the Chairman on the way in which he has carried out his duties through so many difficult years."

The report and balance sheet were adopted *nem. con.*

The CHAIRMAN introduced the Council's recommendation to alter the rules of the Society. At a very well attended meeting of Council a short time ago the question of appointing a President had been considered and rules drafted as follows:—

> RULE V. (19). (Line 2) delete the words "for one year."
> (Line 4) delete the words "In his absence . . . in succession."
>
> RULE V. (19*a*). "At a meeting subsequent to the Annual General Meeting in each year the Council shall appoint a Chairman, who shall take office in the following October and hold office for one year. He shall be an *ex officio* member of the Council and of all committees appointed by the Council and shall be entitled to preside at all meetings at which he shall be present in the absence of the President. He shall not be eligible for re-election on the expiry of his year of office."

(19*b*). The Chairman shall be nominated by the following method:—

(i.) At a Council meeting to be held in the month of April in each year members of Council shall be invited to submit in writing the names of possible candidates for the chair.

(ii.) At the following monthly Council meeting a further opportunity shall be given for the submission of names.

(iii.) At the June Council meeting a Chairman-elect shall be selected by ballot among the Council from the names thus submitted.

(19*c*). The Vice-Chairman of the Society shall be the retiring Chairman. He shall be an *ex officio* member of the Council and shall hold office for one year. He shall be entitled to preside at all meetings at which he shall be present in the absence of the President and Chairman.

That was carried unanimously. The Society had never fixed on the procedure of appointing a chairman before. The method proposed here had been tried in other societies and it was thought would be beneficial here. It was also agreed that it would be of advantage to have an annual tenancy of the chair. The expedient suggested as to the election of a vice-chairman is usual. By this method the continuity of policy so essential in our case will be best carried on.

Mr. CHARLES BRIGHT asked if it was the case that they intended to have a president as well as a chairman. Surely to have both was unusual. He supposed that the president would be a picturesque figurehead. In years to come, when aeronautical knowledge was more commonly held, he surmised that the office of president would drop out. He asked what other technical societies had both offices.

Dr. WALMSLEY cited the case of the Association of Technical Institutions of which Sir Alfred Keogh was the President, and where there was also a Chairman of Council.

Sir MACKENZIE CHALMERS pointed out that under the rules as drawn the vice-chairman could be elected chairman after his year of office as vice-chairman. There was, he thought, no possible objection to this.

The Council's recommendation was then put to the vote and carried.

Dr. WALMSLEY: I do not know if I am the senior member of Council here to-day, but as I learn from the remarks that have fallen from our Chairman this afternoon that this is the last time probably that he will preside over us, I should like to propose a vote of thanks to him for presiding not only over this meeting to-day but for his long period of office. He has held this office for seven years of the most astonishing developments that have taken place in the history of aeronautics, it would be no exaggeration to say since 1866. At least, that is my opinion. During that period at the beginning was a period of stress and strain, but he has brought us through the storms and quicksands to deep waters of prosperity. We have only to compare the figures that have been presented to us on the balance sheet this afternoon with those of seven years ago to see how different things were. Aeronautics is now coming into its own. For long years it was looked at askance, it was looked on as a sort of hobby, and even scientific men scoffed at it. One heard so often of Icarus that one sometimes became very tired of his name and wondered if such a man ever existed. But the Society went on under its able Chairman, and we owe him—I venture to suggest—a very deep debt of gratitude for his services during that period. I did not understand that it was to be our Chairman's last attendance until I came in. I need not trouble you with further remarks to show you how the Society has prospered in his hands. The title of the Society is one sign of its progress. I ask you to concur in a very hearty vote of thanks.

Dr. STANTON seconded the resolution, which was put to the meeting by Dr. Walmsley and carried with acclamation.

General RUCK: I am deeply indebted to you for your very kind vote of thanks. It has been a period of stress and strain it is true, but also a period of intense interest which has amply rewarded me. I wish to thank my fellow members of Council and indeed the members generally for the way in which they have aided me, and I hope I shall take away with me their affectionate regard. (Applause.)

The Scrutineers then presented the result of the ballot for ten Members of Council. Sixteen candidates had offered themselves and the ten successful names were as follows:—

Sir Robert Hadfield, F.R.S.	200	votes.
F. Handley Page, C.B.E.	199	,,
A. E. Berriman, O.B.E.	178	,,
Lieut.-Col. T. R. Cave-Browne-Cave, C.M.G. ...	177	,,
G. Holt Thomas	176	,,
Sir Mackenzie Chalmers, K.C.B.	166	,,
A. Ogilvie, C.B.E.	160	,,
Lieut.-Col. Alan Burgoyne, M.P.	159	,,
Lieut.-Col. H. T. Tizard	157	,,
Lieut.-Col. M. O'Gorman, C.B.	148	,,

The CHAIRMAN said the poll had been a heavy one and he was sure that all would support him in moving their best thanks to the Scrutineers for their really arduous labours.

This was seconded by Major Low and adopted.

The proceedings then terminated.

Notice.

The lecture by Captain A. P. Thurston, D.Sc., on the "All-Metal Aeroplane," announced for earlier in the Session and postponed on account of the lecturer's illness, will be given on May 14th, at the Royal Society of Arts, at 8.0 p.m. Brig.-Gen. R. K. Bagnall Wild, C.M.G., will preside.

AERIAL
(The Royal

GENERAL INCOME AND EXPENDITURE ACCOUNT

Income.

	£	s.	d.
By Annual Subscriptions	1,229	17	6
,, Dividend on War Loan...	37	16	6
,, Donations	878	5	0
,, Journals, Pamphlets, etc., Balance	691	1	9
,, Sundries	9	5	5
	£2,846	6	2

BALANCE SHEET,

Liabilities.

	£	s.	d.	£	s.	d.
Nominal Capital	1,000	0	0			
Divided into 20 Shares of 1/- each and 999 Shares of £1 each.						
Capital issued and called up:—						
11 Shares issued and fully paid up				0	11	0
Sundry Creditors				213	10	3
Subscriptions paid in advance				114	9	0
Reserves and Apportionments				18	15	0
Reserve Fund:—						
Entrance Fees and Life Compositions of present Members as at 31st December, 1917	1,203	5	0			
Receipts during 1918	664	17	0			
				1,868	2	0
Revenue Account:—						
Surplus 1917 Balance	206	0	2			
Excess of Income over Expenditure 1918, exclusive of Entrance Fees	512	15	4			
				718	15	6
				£2,934	2	9

SCIENCE, LTD.

Aeronautical Society).

FROM 31st DECEMBER, 1917, to 31st DECEMBER, 1918.

Expenditure.

	£	s.	d.	£	s.	d.
To Office Rental, Lighting and Insurance	359	2	0			
,, Salaries	597	3	11			
,, Educational Lectures	754	19	2			
,, Exhibitions and General Meetings	216	3	5			
,, Subscriptions	15	15	0			
,, Printing, Stationery, etc.	76	19	7			
,, Postages, Messengers, etc.	76	10	0			
,, Library Expenditure	76	9	3			
,, Office Expenses	63	2	8			
,, Committees...	86	15	10			
,, Audit Fee	10	10	0			
				2,333	10	10
,, Balance being in excess of Income over Expenditure				512	15	4
				£2,846	6	2

31st DECEMBER, 1918.

Assets.

	£	s.	d.	£	s.	d.
Cash at Bank—Coutts and Co.	692	6	5			
Cash in hand	46	8	11			
				738	15	4
Investments:—						
£750 of 5% War Loan	709	6	4			
£100 of 5% War Bonds...	100	0	0			
				809	6	4
Office Furniture, Printed Books, Bindings, Stationery, Old Prints, etc., as per last Balance Sheet ...	307	11	8			
Additions during year...	15	0	0			
				322	11	8
Stock of Journals, etc., at Society and with Society's Printers, as estimated by the Secretary				20	0	0
Sundry Debtors, including Subscriptions owing				1,032	4	5
Reserves for amounts paid in advance				11	5	0
				£2,934	2	9

I beg to report that all my requirements have been complied with by the Directors and Officers of the Company, and that in my opinion the foregoing Balance Sheet is properly drawn up so as to exhibit a true and correct view of the state of the Company's affairs, according to the best of my information and the explanations given to me, and as shown by the books of the Company.

(Signed) JAMES E. WARD, *Chartered Accountant*,

1st April, 1919. London and Birmingham.

ROYAL AERONAUTICAL SOCIETY.

Council's Report 1918-19.

In presenting the 54th Annual Report, the Council have pleasure in drawing attention to the prosperity and generally improved standing of the Society, which were such marked features of the report last year, and which can again be emphasised. The Society is continuing to grow in numbers and influence, so that every confidence may now be felt that it should have before it a great and prosperous future.

Title.

The Council are glad to have the honour to announce what is already well known to the members, that on June 25th, 1918, Sir William (now Lord) Weir, then Secretary of State to the Air Ministry, conveyed to the Society the information that His Majesty had been graciously pleased to confer on the Society the dignity of being henceforth known as the Royal Aëronautical Society in recognition of the Society's work.

Membership.

In January, 1918, the membership of the Society stood at 690, a considerable advance on the preceding year, but in January of the present year this figure had increased to 1,045. The Council considers that the fact that the membership has reached the figure of one thousand should be commemorated in a suitable manner together with the jubilee of the birth of the Society, which took place during the war. It is therefore proposed that an evening entertainment or conversazione should be given by the Society during the month of June, at a date to be named later.

Branches.

Progress has been made with the organisation of branches of the Society. The branch at Manchester is organised and has already held a number of successful meetings. In connection with this branch the College of Technology (University of Manchester) has arranged a course of lectures on aeronautics, which has been well attended. The Hendon branch has a large membership and is now completing its final arrangements. Members are requested to co-operate with the Executive of the Society in forming additional branches where the conditions in their own districts are favourable.

Increase in Council.

In consequence of the greatly increased work of the Society it was found desirable to increase the number of the Council, and accordingly on November 20th, 1918, Rule IV. (6) was altered by resolution at an Ordinary General Meeting of the Society, increasing the number of the Council from 16 to 20. The members co-opted to fill the vacancies thus created were Lieutenant-Colonel Alan Burgoyne, M.P., Lieutenant-Colonel T. R. Cave-Browne-Cave, Brigadier-General Sir Capel Holden, F.R.S., and Major R. V. Southwell.

Conjoint Board of Scientific Societies.

In October the Society received an invitation from this Board to become one of its constituent societies. Major-General R. M. Ruck, C.B., C.M.G., R.E., was elected as the Society's representative on the Board for the current year.

The Technical Terms Committee.

This Committee has now completed the present stage of its work and presented its preliminary report. It should be observed that the difficulties of the questions involved was so great, in view of the wide divergencies in terminology existing among the various sections of the aero-technical world, that not only was the labour of the Committee enhanced, but the necessity of their issuing a report, even if only hastily completed, was made evident. The Committee draw attention to the tentative nature of certain of their proposals. The Glossary prepared by the Committee is therefore issued as a working compromise. The Committee do not regard their work as finished, but will, as occasion arises, issue revised editions. The Committee have embodied in their Glossary a system of notation for use in aerodynamical calculations. This, after submission to the Advisory Committee for Aeronautics, was approved by them for issue as a provisional system on which comment is invited. The Council desire to express their thanks to Lieutenant-Colonel O'Gorman and the other members of this Committee. The Committee has met weekly for a period of 18 months and individual members devoted a great deal of time to the consideration of the various problems involved. The task was complicated by the differences of nomenclature which have grown up throughout the world, and as it was desirable to make the Glossary as international as possible much correspondence was involved. The Committee, as appeared in the last report, took its final form as the result of co-operation between the Society, the Engineering Standards Association, the American Advisory Committee on Aeronautics and the International Aircraft Standards Board of Washington.

The Committee as finally constituted was as follows:—

Chairman: Lieut.-Colonel M. O'Gorman, C.B., R.A.F. (Engineering Standards Association and R.Aë.S.).
L. Bairstow, F.R.S. (Royal Aëronautical Society and Air Ministry, Technical Department, Experiment and Research).
Lieut.-Colonel Briggs, R.A.F. (Royal Aëronautical Society).
W. Cannell (Society of British Aircraft Constructors).
Lieut.-Colonel T. R. Cave-Browne-Cave, R.A.F. (Air Ministry, Airship Department).
Major T. G. Clarson (Air Ministry, Aircraft Equipment).
Captain A. C. Day, R.A.F. (Admiralty and War Office).
Captain A. F. C. Pollard, R.A.F. (Air Ministry, Technical Department, Instrument Section).
Captain F. M. Harding, R.A.F. (Air Ministry, Technical Department).
A. Winter-Moore (Air Ministry, Aircraft Equipment Department).
Major W. H. Ewen, R.A.F. (Air Ministry, Aircraft Equipment Department).
C. G. Grey (Royal Aero Club).
Lieut.-Colonel J. H. A. Landon (Air Ministry, Technical Department, Applied Design).
Major A. R. Low, R.A.F. (Royal Aëronautical Society).
R. Borlase Matthews, A.M.I.C.E. (Royal Aëronautical Society and Air Ministry, Technical Department, Applied Design).
Captain J. K. Mountain (Air Ministry, Aircraft Equipment).
Major Myers, R.A.F. (Air Ministry, Aeronautical Inspection).
A. S. A. Ormsby (Patent Office).
R. K. Pierson (Society of British Aircraft Constructors).
W. G. Renals (American Advisory Committee for Aeronautics).
F. J. Selby (Advisory Committee for Aeronautics and National Physical Laboratory).
Sir Napier Shaw, F.R.S. (Meteorological Office).
Captain Waters, R.A.F. (Air Ministry, Technical Department, Drawing Office).

To these individually the Council desire to offer their acknowledgments.

Civil Aerial Transport.

In the last report reference was made to the efforts which were being made by the Society to promote the cause of civil aerial transport. This movement has now attracted considerable attention and is widely recognised as of the utmost national importance. The efforts of the Society have been continued during the past year and three public lectures have been delivered on the subject under the auspices of the Society to very large audiences in the Central Hall, Westminster, by Mr. Holt Thomas, Brig.-Gen. Lord Montagu of Beaulieu and Mr. C. Grahame-White. In the first and last one of these the chair was taken by the Secretary of State to the Air Ministry for the time being, Lord Cowdray at Mr. Holt Thomas' lecture and General Sir John Seely at Mr. Grahame-White's. The Council offer their thanks to both chairmen and lecturers for their valuable help. In dealing with this subject one further remark may be made. For some time it had been feared that the termination of hostilities might be accompanied by a decline in the Society's membership as a natural result of the necessarily restricted output in the aircraft industry. Fortunately this prediction has been falsified. The widespread and well-founded hopes for a great future in civil aerial transport which exist throughout the country have given the Society an increased hold upon the public and its numbers have continued to grow since the Armistice as possibly an enhanced rate. The great advance which took place in aeronautical science and industry is one of the benefits which we may claim from the Great War, and there is some satisfaction for the oldest aeronautical institution in the world in turning to the arts of peace the scientific knowledge which it developed and acquired in the terrible days of conflict. The Council strongly urge the foundation of local branches of the Society in connection with this matter. Much might be done to further the introduction of civil aerial transport in this way by the encouragement of lectures and discussion on the subject.

Popular Lectures.

The Council understand that a certain number of members of the Society hold the view that there has been an undue proportion of popular lectures delivered during the past year. The Council appreciate the fact that there is much to be said in favour of their contention, but would point out that the times were unusual, that owing to the war there was a dearth of interesting technical matter which could be published and that the advent of civil aerial transport requires special attention of a popular nature to be devoted to it. With normal times there will be a return to the proper proportion of lectures, scientific and technical.

Meetings.

A very full and interesting course of lectures was arranged for the current session. During the war, in the national interests, the censorship has rendered it impossible to publish much of the more recent scientific work. But now the necessity for secrecy has to a great extent ceased, and it is hoped that in future years the latest research will be promptly made public at the Society's meetings.

In spite of the precautions observed, however, the lectures offered to the members were undoubtedly of the greatest value and interest, and the Council desire to acknowledge the kindness of Major-General Sir W. S. Brancker, K.M.G., Major L. N. G. Filon, F.R.S., Sir Robert Hadfield, F.R.S., Lieut.-Colonel M. O'Gorman, C.B., Surgeon-General Sir Alfred Keogh, G.C.B., L. Bairstow, F.R.S., Lieut.-Colonel T. R. Cave-Browne-Cave, Brigadier-General R. K. Bagnall Wild, C.M.G., R.E., Lieut.-Colonel A. Ogilvie, R.A.F., Dr. T. E. Stanton, F.R.S., Brigadier-General E. M. Maitland, D.S.O., Lieut.-Colonel Jenkin, R.A.F., for their support in presiding at the meetings. The Council also offer their most cordial thanks to Major Cochrane Patrick, D.S.O., M.C., R.A.F., Major A. R. Low, R.A.F., Major Philpot, R.E., Captain W. S. Farren, M.B.E.,

Dr. L. E. Stamm, R.A.F., Captain R. J. Goodman Crouch, Mr. F. W. Aston, D.Sc., Captain F. S. Barnwell, C.B.E., Mr. H. Levy, Lieut.-Colonel T. R. Cave-Browne-Cave, Captain A. P. Thurston, D.Sc., Prof. F. C. Lea, Major H. E. Wimperis and Lieut.-Colonel H. G. Lyons, F.R.S., for the series of admirable lectures placed before the Society.

The Wilbur Wright Lecture.

This lecture for 1918 was held in the Central Hall, Westminster, on June 25th. An audience of over 3,000 assembled to hear Dr. W. F. Durand, Chairman of the American Advisory Committee on Aeronautics, lecture on "Some Outstanding Problems in Aeronautics." Sir William Weir, Secretary of State to the Air Ministry, presided. The Council express their cordial thanks to both these gentlemen.

Juvenile Lecture.

The success of the juvenile lecture last year encouraged a repetition and accordingly, on January 8th, a second lecture for the children of members and friends was arranged. A very large audience of young people assembled. The thanks of the Society are due to Mr. Handley Page for his highly interesting lecture and to Lieut.-Colonel Alan Burgoyne, M.P., who presided.

The Exhibit of Enemy Aircraft.

At the request of the Air Council the Society undertook the distribution of the interesting and valuable collection of the war relics at the Agricultural Hall, Islington. The objects selected by the Society were given to it in trust by the Government and have been distributed by it on permanent loan to the following councils and institutions:—The Universities of Bristol, Leeds, Belfast, Liverpool, Birmingham, Sheffield and Wales; the College of Technology, Manchester; the Technical College, Cardiff; the East London College; the Armstrong College, Newcastle; the Technical College, Swansea; University College, Southampton; the Heriot Watt College, Edinburgh; the Technical College, Glasgow; University College, London; Technical School, Lincoln; Northampton Polytechnic, London; Harris Institute, Preston; South-Western Polytechnic; Technical School, Stockport; Tottenham Polytechnic; Technical School, West Ham; and the Corporations of Gravesend, Ramsgate, Southend, Leeds and Swansea; the Technical School, Blackburn; the Borough Polytechnic Institute, Southwark; the Corporation of Ipswich; University College, Exeter; the Technical Institute, Coventry; the Royal Technical Institute, Salford; Tonbridge School, and the Imperial College of Science.

Demobilisation of Officers and Others in the Flying Services.

The Council, upon the declaration of the Armistice, appointed a Special Committee to consider the problems likely to arise in relation to the employment of members of the Society demobilised from the Services, and the cognate problems existing in relation to aeronautical education. It has throughout advised the Ministry of Labour in relation to these questions. It is proposed to circulate, where it is likely to be of service, a list of members of the Society who have asked for assistance in obtaining employment, and it is hoped that all members will do their utmost to assist fellow members in these critical times.

Qualifications for Membership.

The qualifications which should be required of candidates for technical membership of the Society has again been under consideration on various occasions during the year. In connection with this the question of the desirability of instituting examinations, and the acceptance in lieu thereof of the degrees and diplomas of certain universities and colleges came under review. The Council do

not think that the time has yet come to institute examinations by the Society, but inquiries are being made with a view to preparing a list of universities, colleges and schools where classes for aeronautical training have been established and where degrees or diplomas in this subject are granted, and of ascertaining which aircraft and other works would be likely to offer an adequate technical training.

The Journal.

In January, 1918, in consequence of a general demand, the experiment was made of issuing the JOURNAL as a monthly instead of a quarterly as heretofore. At the same time, in consequence of the greatly increased cost of printing and paper the price was increased from 1s. 6d. to 2s. 6d. A publication of this sort is such a heavy expense to a learned society that the experiment was embarked upon with some anxiety, but the result has fully justified the action taken.

The Library.

Recent issues of new books on aeronautics have been added as published, while the collection of bound issues of trade and scientific journals dealing with aeronautics throughout the world has been kept up to date and is nearly complete. Upon the declaration of peace an endeavour will be made to obtain various German publications, which it has been impossible to obtain during the continuance of the war.

Abstracts.

Under the arrangement with the War Office a monthly issue has been made of abstracts from the world's Press on aeronautics. It may be opportune detail to the members how the abstracts on aeronautics have been prepared. The War Office collected the material, the Society and the National Physical Laboratory jointly appointed the abstractors. The matter thus procured was issued by the War Office under the editorship of Lieut.-Colonel Wake. The Council desire to place on record their sense of the very useful services of Colonel Wake in the matter.

The Secretary.

The Council desire to express their keen appreciation of the work of the Secretary during the past year; the large increase in membership and highly satisfactory condition of the finances is due in no small measure to his exertions in the interests of the Society. His business qualifications have been specially useful as regards the publications of the Society, which have been a matter of considerable anxiety and difficulty during the war.

The Council also desire to acknowledge with appreciation the valuable assistance given to the Society by Miss St. Barbe, the Assistant Secretary.

Finance.

The financial position of the Society, as shown in the accompanying balance sheet, is satisfactory and continues to improve. In January of the present year a further investment of £500 was made in War Loan, bringing the investments of the Society in this stock up to £1,350. The labour of transacting the office business of the Society would be made considerably lighter and much expense would be saved if members would, wherever possible, pay their subscriptions by means of a banker's order.

The Honorary Officials.

The Council desire to express their most cordial thanks to Messieurs James Ward and Co. for their services in auditing the books of the Society, and to Mr. B. Woodward, the Honorary Solicitor, who has advised them throughout the year.

THE ROYAL AERONAUTICAL SOCIETY.

The third meeting of the Session was held in the Hall of the Royal Society of Arts, London, on Thursday, December 5th, 1918, Sir Robert Hadfield, F.R.S., presiding.

The CHAIRMAN: I have to announce with regret that Brigadier-General R. K. Bagnall-Wild, C.M.G., who was to-night to have delivered a lecture on "Shop Practice in Respect to Aircraft Steels," is unable to be present as he is suffering from the popular malady, but I know those present will join me in hoping that he will soon be better. We are, however, fortunate in having as a substitute his able assistant, Major Philpot, who has done a great deal of valuable work on this subject and has been kind enough to consent to take General Bagnall-Wild's place on this occasion. I take this opportunity of thanking the Society for the honour they have been good enough to confer on me in electing me as a Fellow. I hope that I will not prove to the Society that I am a "bad Fellow," but a "jolly good Fellow" who has their interests at heart. At any rate I am desirous of being so as I have had a tender place in my heart for the technical man who, to my mind, is not excelled by anyone in his devotion to the cause of the King and the Empire. I also take this opportunity of expressing my appreciation of the valuable services our gallant airmen have rendered in the war. You all know the great work they have done, and if the Armistice had not been signed Berlin would shortly have been subjected to similar attacks to those to which they have treated us. From what I have heard, I venture to think they would have greatly regretted they had ever visited London town. The paper to-night is on "Steel," and a subject which indirectly concerns the paper is that of Sound Steel, which is the foundation of all good steel.

SOUND STEEL.

The Elimination of Unsoundness.

The subject of occluded gases has during my life been of particular fascination, as in the early days of steel castings the difficulties which then had to be overcome to get rid of occluded gases were literally enormous. The very useful element silicon, which prevents the occlusion, was hardly obtainable except in combinations which caused as much trouble as the unsoundness itself. There were no high percentage ferro-silicons with low carbon available or silicon spiegels. Aluminium was unknown for practical purposes. Manganese, whilst useful, was only a partial cure. Moreover, it was thought that the element silicon produced a material with inferior qualities; in fact, the presence of even as much as two-tenths per cent. of silicon was looked upon with holy horror. We owe, therefore, a great debt of gratitude—it is almost impossible to say how much—to the French metallurgists whose names I give below, and who perfected and introduced the successful production of ferro-alloys containing high percentages of silicon, such as silicon spiegel, also ferro-manganese, and to others, including Hunt of Pittsburgh, who later brought about the production of cheap aluminium. The proper and most suitable manner of making the addition of these elements to obtain soundness in steel had also to be most carefully studied, as otherwise the remedy might be almost worse than the disease.

The Terre Noire Co.'s Work.

The great advance in the production of sound steel was largely due to three Frenchmen, MM. Euverte, Pourcel and Gautier, of the Terre Noire Works, France, who were amongst the first to give us the necessary silicon and manganese alloys of the proper composition and character which have enabled us to produce

sound steel. It is always satisfactory and pleasant to be able to trace and give the credit where it is due, and in this case it can be done.

Several papers were read on the subject by Gautier before the Iron and Steel Institute in 1877 and 1881 on "Processes of Producing Sound Steel Castings." These aroused great attention, in fact, sent a flutter through the metallurgical world at the time. I well remember the excitement created by these admirable papers, freely given to the world by the French investigators in question.

It is without doubt from the work of these metallurgists who pioneered the way that we are so largely benefiting to-day. I can frankly and truly say that the German metallurgists never gave help of this nature, they have only copied, absorbed, and made use of the principles of French, British, American, and Swedish metallurgists. I cannot remember any specific instance of the Germans teaching us any basic principles in ferrous metallurgy.

Amongst the magnificent exhibits of the Terre Noire Company at the Paris Exhibition of 1878, a series of specimens was shown illustrating this firm's research work. This then new material, known as "cast steel without blowholes," made a great sensation in the metallurgical world. I have not forgotten the remarkable effect upon my own mind, and freely admit my indebtedness to these scientific workers in the great French firm mentioned.

When about twenty years of age I translated the valuable pamphlet issued by this firm giving very complete particulars of their exhibits, methods of manufacture, analysis, composition, and mechanical qualities. The new material was there described as one destined "to be of great service to artillery and industry." Its manufacture necessitated the employment of highly silicious pig iron, silicon spiegel, also 60 to 80 per cent. ferro-manganese, which the Terre Noire produced and offered to the world. These alloys were produced in the blast furnace and contained combinations of iron, silicon and manganese, eventually known as silicon spiegel. The following were the analyses of some of these:—

		C.C.	Si.	S.	P.	Mn.	Fe.
Alloy No.	1 ...	2.65	10.20	—	.185	20.50	66.75
,,	2 ...	2.65	7.45	—	.178	19.50	71.50
,,	3 ...	2.30	5.45	—	.145	13.00	79.00
,,	4 ...	2.10	5.55	—	.140	6.50	85.50

The Terre Noire Company were also one of the first if not the first firm to produce on a large scale the alloy known as ferro-manganese, which is to-day of such enormous importance and interest to every steel maker in the world. Their material was sold at about £120 per ton and the same material just before the war had reached the figure of about £9 per ton for 80 per cent. ferro-manganese produced in the blast furnace and of excellent quality.

The Production of Intricate Steel Castings.

It is now possible to produce steel castings of all kinds and weights, provided the section is not too thin, of perfectly sound material. As an instance, I will describe a particular application, namely, hydraulic cylinders for cotton baling presses with the production of which my firm has been most successful, largely owing to the careful study we have made of the art of producing sound steel. These cylinders cast of steel and not forged or pressed in any way, are of particularly difficult nature, in some cases running up to lengths of over 30ft. Such considerable length is for the purpose of obtaining a very long stroke in pressing at the same time as many cotton bales as possible. The complete presses are made in this country and sent out to India, Egypt, and elsewhere. The ram is usually only small, 7in., 8in. or 9in. diameter, the walls of the cylinders must be as thin as possible in order to save weight, and yet must stand the severe hydraulic

test pressure of about 4 tons per square inch, and they must be guaranteed to work constantly day and night during the baling season at pressures up to three tons per square inch.

In order to bring home to those present the problem which has had to be solved by the maker of these cylinders in cast steel, not forged or otherwise worked, I have had a diagram made in full size section of a particular cotton press cylinder. In this case the diameter of the ram was 9in., stroke 26ft., the working and test pressures ranging from three to four tons per square inch. Picture to yourself, therefore, a cylinder of this nature, which is about 30ft. in overall length including the sinking head, the internal portion of which is subjected without intermission during the baling season to the severe hydraulic pressure mentioned—some three tons per square inch. There must not be the slightest weeping or oozing through the walls, as if the pressure was not fully maintained the baling would be a failure, that is, the bales would not be packed sufficiently tightly, and therefore occupy far too large a volume in shipment from the district where the cotton was produced to the cotton mills in Lancashire and elsewhere.

To further bring home the severity of this hydraulic test, it may be stated that the total internal area of the working surface subject to the high pressure mentioned, amounts to no less than 10,400 square inches, in not one square inch of which must there be the slightest unsoundness or porosity.

To give some idea of what this testing pressure means, it may be stated that it is about 100 times the pressure at the nozzles of the hosepipes used by the London Fire Brigade when throwing a stream of water 1½in. diameter to a vertical height of 165ft. This will be better appreciated when it is remembered that the Nelson Monument in Trafalgar Square is 145ft. in height.

In the early eighties of the last century these cylinders were made of forged and fluid compressed steel produced by the Whitworth process, for which a very high price was paid because reliance could be placed upon them to stand this constantly severe work and the pressures mentioned. However, by the careful study of the cause and action of occluded gases, their prevention, the best steel for the purpose and the best methods of moulding the cylinders and the pouring of the steel, my firm many years ago gradually overcame the difficulties and became able to meet these severe requirements by making a hydraulic cylinder costing about half the price of the Whitworth expensive one. Thousands of such cylinders, as shown by the photograph No. 516 now on the table and the diagram on the wall, are in use all over the world, giving entire satisfaction.

The problem of satisfactorily producing such an article is greatly increased and intensified by the severe contraction met with in the cooling down of molten steel from about 1,540° C. This contraction is slightly over ¼in. per foot, thus adding to the practical difficulties experienced, the mould for such cylinders being required to be not less than 7in. longer than the cylinder itself is when cooled down, in other words, the cast steel cylinder itself has to contract this considerable amount between its length as cast compared with its dimensions when cold.

I have referred to this at length because the example is a typical one and helps to explain how important has been the advantage of studying in the past by means of scientific methods the question of getting rid of occluded gases. It should be remembered that fluid steel is at a very high temperature, and as in the first part of the pouring into the mould of the cylinders referred to there is a drop of no less than about 30ft. in depth down the thin walls of the cylinder formed of sand or composition, that is, the space forming the walls of these cylinders for cotton presses is in some cases only about 1½in. in width or thickness, and is very seldom more than 2¾in. Bearing in mind, too, that the fluid steel when being poured is at the temperature of some 1,540° C. and that gases are given off from the sides of the mould which is formed of fire resisting material such as silica sand, composition and other mixtures, it will be readily seen,

specially with regard to the early poured steel dropping this full and long distance, how great must be the tendency of the molten steel to absorb gases and become unsound. It must be remembered that molten steel, which is quite fluid at from say, 1,500 to 1,540° C., immediately below about these temperatures, can no longer be termed really fluid, it has more the consistency of thick cream, and not many degrees lower it is quite pasty. The great difficulties, therefore, of working within these narrow margins of fluidity and semi-solidity will be readily understood. The only wonder is that under these severe conditions the steel remains sound and the finished cylinder so successfully stands the high working hydraulic pressure before mentioned. It will, therefore, be admitted that the study of methods which get rid of occluded gases is of the highest service to the constructive engineer, and that our gratitude is due to those French metallurgists who, in the early days of the development of ferrous metallurgy, attacked this severe and complex problem of giving us alloys by the aid of which we could obtain the necessary sound steel free from blow holes, occluded gases, and other defects.

The Use of Silicon.

It may be interesting to add a few special comments on the nature of the use of the element silicon as a solidifier, now found so important and necessary in the production of sound steel.

The use of silicon itself is not new, in fact it is probable that the old Sheffield crucible steel to some extent owed its high quality to this element. In the melting of this kind of steel, clay crucibles made not of graphite or black lead but of clay and known as "pots" were always employed. At the bottom of the pot, which contained a hole formed by the spindle of the mould making up the form of the crucible, there is a separate stand or bottom of firebrick. In order to seal up this hole it is the common custom to throw in a few handfuls of highly silicious sand, which, on reaching the high melting point of the steel being produced, is fused, and this causes the bottom to adhere to the crucible itself. In so fusing, and owing to the presence of this silica at the bottom of the pot, some of the silicon present is reduced and a small percentage of silicon eventually finds its way into the steel during the time it is being melted in the crucible.

The following is an analysis of a sample of crucible steel for drills made nearly a century ago by Huntsman, the inventor in this country of crucible cast steel.

C.	Si.	S.	P.	Mn.
1.40	.17	.047	.017	.18 per cent.

It will be noticed that the silicon is present in quite perceptible percentages namely, nearly two-tenths of one per cent., which would materially assist the reduction of unsoundness and blow-holes.

The great modern development of the use of silicon for getting rid of occluded gases was, however, as I have said elsewhere, due to the Terre Noire Company of France, which did so much for the advancement of ferrous metallurgy.

Special Committee.

It may possibly be remembered by some of those present that at the recent meeting of the Iron and Steel Institute, I suggested that the question of the production of steel free from occluded gases, segregation, piping, and other defects, ought to be studied by a special committee.

I then pointed out that very large quantities of steel are unnecessarily melted over and over again with the loss of much coal which might be saved if the matter were studied from a scientific point of view. There are also large losses of iron by oxidation in re-melting. The whole problem is one of such urgent importance that there is, indeed, room for the appointment of a special committee to deal with it. The Advisory Council for Scientific and Industrial Research would probably be willing, if properly approached, to place a sufficient sum of money

at the disposal of such a committee which would amply defray all the expenses of the investigation.

Since then I have received an important communication from the head of one of our Government departments strongly urging that this suggestion of mine should be carried out. In view of the scarcity of iron and steel in all countries, brought about by the enormous war and other demands, it behoves us to take every possible care and economise to the utmost degree our supplies of the most important metal in the world—iron—upon which the safety and comfort of the inhabitants of this world of ours so largely depend.

In the Presidential Address delivered a few days ago by Sir John Aspinall, President of the Institution of Civil Engineers, he pointed out that we ought to consider the question of steel instead of wood railway sleepers. This alone would mean an annual increased demand of 300,000 tons of steel. Where is this to come from, seeing the heavy demands for shipbuilding, repairs and renewals after the war, and the thousand and one applications of steel? Hence the desirability of studying economy in our use of steel.

When it is remembered that in America alone 42 million tons of steel were produced in 1917, and that the total of the world's production was probably 75 million tons, it will be seen that an economy of even only 10 per cent. would mean the saving of no less than 7½ million tons.

With unsound steel there cannot be good works practice. Many failures are due to unsoundness of various kinds—piping, segregation, loose structure and definite unsoundness from blow-holes originally present. It is not altogether to be wondered at that it is not easy to obtain such steel. Iron is one of the most easily oxidised of metals. It is estimated that some 18 million tons per annum are lost by oxidation or corrosion produced by atmospheric effects, especially in this watery climate. If iron is, therefore, subjected to oxidation at atmospheric temperatures, the liability for it to be so when heated to a temperature at which it is molten and liquid, namely, about 1,520° C., is much greater. Moreover, at such high temperatures iron takes up or absorbs gases very easily and readily. In other words, it occludes gases and holds them, or some of them, in solution just like the gas in soda water in an unopened bottle. Let us consider what is meant by a temperature of about 1,520° C. It is much beyond and higher than the white heat of the highest welding temperature in the forge or smith's fire. It is fifteen times the temperature of boiling water, which is, as we sometimes know to our sorrow, quite hot enough to make us feel very uncomfortable. It is about four and a half times the temperature of molten lead and more than twice that of the melting point of aluminium and 50% greater than that of molten copper. It is no wonder, therefore, that at such a high temperature there is liability to take up injurious gases. A chart is exhibited showing the various grades of temperatures from that of absolute zero to what is believed to be the temperature of the sun. In the early days of my metallurgical life an attempt was made to reduce and get away from the trouble by producing harder steel, which meant steel with higher carbon, consequently a more brittle steel, and one which melted at somewhat lower temperature, thus to enable some of the gases to escape more readily. The harder steel, however, means a more brittle steel, consequently for many years steel castings could not be trusted to perform the severe work required in the modern development of railway, tramway and engineering work of all kinds. In the milder steels of those days (that was of lower carbon) if it had not been for the fact of the softer steel more readily welding, in other words, if the blow-holes present did not prevent welding together of the steel by heating, there was no doubt it would not have been possible to obtain reliable soft steel at all. I may mention that my father nearly went bankrupt owing to the lack of scientific assistance in his endeavours to produce sound steel.

Part Played by the Steel Maker.

As regards the part played by the steel maker in aeronautics, all I can say is

that we metallurgists have done our best, in fact from what I hear we have produced so much steel that it has not been possible to work it all up. Therefore in quantity we have not been found wanting in the help we have tried to render, even to risking, and in many cases giving, their lives to protect their country.

Newer Steels Less Costly.

I am at present working on the problem and believe it will be possible to greatly reduce the call for expensive steels to meet the modern requirements of motor and aeroplane work. For example, here is a steel containing no nickel, chromium, vanadium, tungsten, or other expensive element, the results obtained on which show material varying, according to the heat treatment, as follows:—

Yield Point	... ...	From 39 to 64 tons per sq. in.
Maximum Stress	...	From 41 to 72 tons per sq. in.
Elongation	... ...	About 20% to 31%.
Reduction of Area	...	From 50% to 70%.
Fremont Shock Test	...	6 kgm. and 19° bending angle to 21 kgm. by 90°.
Izod Shock Test	...	31 ft. lbs. to 88 ft. lbs.
Ball Hardness	... ...	156 to 350.

All these qualities can be obtained without the use of the expensive elements just mentioned. Full particulars of the tests obtained are given in the accompanying table No. T. 7465b.

Higher Tenacity Steels.

With regard to the production of steel of high tenacity, in table No. L.P. 10 will be found data showing that it is possible to obtain material with no less than 125 tons per square inch tenacity, 100 tons yield point, and with a ball hardness number of 555. Naturally with this high tenacity the Izod test is not specially high, nevertheless it reaches 14 ft. lbs. The same steel reduced to 106 tons tenacity gives 20 ft. lbs. Izod test with a ball hardness number of 477.

Thermal Conductivity.

It has also been thought of interest to add table No. T. 7594b with regard to the thermal conductivity of various steels, because this quality has an important bearing upon the treatment required in forging down in the first place the ingots, then the blooms, and finally the heat treatment of the finished product. I believe that no information has before been given on this subject; in other words, the data set forth is practically new and, I think, most important.

Societies' Building.

There is one other matter which I should like to mention this evening, and I believe you will pardon my referring to it and that it will meet with your approval.

There is no one who has done more for our country in her hour of stress and need than the scientific and technical man. Moreover, we men in this country have our hands and our minds clean, we have never descended to mean and despicable means of fighting. But for the enemy's abominable inhumanity I venture to say without fear of contradiction that not a single bomb would have been dropped, not a cubic millimetre of poisonous gas used, not a single torpedo would ever have been fired against innocent non-combatants in this great war.

But the part of the technical man in this country has not been properly recognised in the past; with a few fortunate exceptions he has no proper home in which to carry on his business, whether as regards managerial requirements or those connected with his meetings where papers are read and discussions take place.

In America there is a wonderful central building, known as the United Engineering Societies' Building, in New York, where the four leading societies,

with a score of smaller ones, have their proper and palatial home. I have always been specially interested in this great building, because I was present at the opening ceremony on April 16th, 1907, and felt sure it had a marvellous future.

In this building the technical men of America, some 60,000 for the societies in question, find a meeting place worthy of their work. I have brought a small model so that you can see what the building in question is like. All told, this Engineering Societies' Building cost some £400,000, of which Mr. Andrew Carnegie gave, with his usual munificence, about half.

Why should not we have the same facilities here, a building in which most of us can meet with dignity and do still better work than in the past. Perhaps before we part this evening you will see your way to pass a resolution that as regards our society we join heartily in the proposals which are now being considered for bringing into existence a home of which all of us would be proud, and one which would be of incalculable advantage to the more efficient carrying out of our work.

I am delighted to have the encouragement and co-operation of your able Chairman, General R. M. Ruck, with regard to this matter of the proposed new building. He and I have already spent a good deal of time in discussing what should be the future policy most likely to bring about the much desired results, which would enable the technical man to have his own building with all the necessary modern adjuncts, including library, council rooms, lecture halls, and possibly even club facilities. There is no institution or society which can better appeal to the Government for aid in carrying out this important project than that of the airman, who has done so much to bring about the magnificent results we now see before us, in which the enemy has been brought down from what he thought the serene height of, shall we say, some 30,000 feet, to now grovel in the dust, to the just contumely of every civilised and right thinking person in the world. We laymen who have never mounted an aeroplane nor attained to the dizzy heights, have indeed the greatest respect for what you are doing and have done in the great war.

In return I think the State might well recognise the desirability of finding and affording every possible assistance in the development of this great new art of industry. It seems incredible to think of the enormously rapid advance of the air forces of the world. It is but a few years ago that the number of aeroplanes could almost be counted on one's fingers, and now we number them by the thousand. One little trifling contribution of our enemy, Germany, in the recent settlement was that she was to hand over some 2,500 of her best aeroplanes.

In all this development I claim that the Metallurgist has had a very considerable share, for without our special steels and knowledge of their proper treatment it would have been impossible to build the magnificent machines we now know are in existence. This has been largely made possible by the use of such special steels in bringing down the weight of the engine to nearly one pound of material for each h.p.

It is estimated that there are in America approximately 500 Engineers' organisations of various kinds, and even then it is estimated that in many communities 30% to 50% of the resident Engineers are not members of any society of Engineers. It is also believed that in America there are from 250,000 to 300,000 Engineers, including assistants such as draughtsmen, inspectors, and professional Engineers. Steps are being taken in that country which we might well follow with a view to improving the condition of the Engineer and his status. One of the objects is the creation of a committee with regard to development. An engineering council, with its seat in the Engineering Societies' Building, to which I have referred, is to assist.

Why should not we in this country, too, have an engineering council, to which the various developments of our profession, whether metallurgical, aeronautical, mechanical, civil, electrical, or other branch, might appeal for help?

SUMMARY OF TESTS ON THE HADFIELD SPECIAL STEEL No. 1515. T7465 B.

ALSO SPECIAL TREATMENT (PATENTED).

Bar No.	Steel No.	Treatment.	Ball Test on Bar	Tensile Test.				Fremont Test.				Izod Test		Ball Test.	Remarks
				Y.P.	M.S.	El.	R.A.	"C" Nick.		"No" Nick		Ft. Lbs.	Angle		
								Kgm.	Angle	Kgm	Angle				
1	1515 C	800° Water, 600° Water	269 277	44	54	23	62	16	60°	60	142° Unbr.	65	17°	252 F. 252 I.	Influence of quenching temperature.
2	,,	850° Water, 600° Water	269	46	55	24	64	16	56°	60	130°	74	33°	252 F. 255 I.	
3	,,	900° Water, 600° Water	269	45	55	22	59	16	62°	60	141° Unbr.	75	20°	255 F. 262 I.	
4	,,	850° Water, 450° Water	364 340	64	72	15	50	5	8°	46	73°	17	2°	332 F. 351 I.	
5	,,	850° Water, 500° Water	340 340	59	66	17	54	7	8°	34	83°	28	3°	293 F. 332 I.	
6	,,	850° Water, 550° Water	321 302	55	62	20	59	7	12°	46	110°	31	4°	300 F. 286 I.	
2	,,	850° Water, 600° Water	269	46	55	24	64	16	56°	60	130°	74	33°	252 F. 255 I.	Range Series.
7	,,	850° Water, 650° Water	262 269	44	53	25	66	14	47°	59	129° Unbr.	88	49°	248 F. 241 I.	
8	,,	850° Water, 700° Water	241 248	38	43	28	69	21	90°	56	132° Unbr.	79	50°	202 F. 238 I.	
9	,,	850° Water, 750° Water	302 311	39	64	26	39	6	13°	50	105°	24	6°	241 F. 241 I.	
13	,,	As Forged		E.L. 20 Y.P. 25	46	21	60	6	19°	35	91° Roaky	38	10°	215 F. 179 I.	As Forged.
14	,,	850° Air		E.L. 28 Y.P. 28	45	29	61	16	70°	49	137° Unbr.	35	7°	170 F. 166 I.	Normalised.
15	,,	750° Furnace		E.L. 26 Y.P. 26	41	31	65	16	73°	46	131° Unbr.	69	35°	156 F. 156 I.	Annealed.

All the above temperatures are in Centigrade figures.

SUMMARY OF TESTS ON THE HADFIELD SPECIAL STEELS

L.P. 10 (T 7741).

Nos. 3614 AND 3620.

Bar No.	Steel No.	Analysis. C.	Si.	S.	P.	Mn.	Cr.	Ni.	Treatment.	Tensile Test. E.L	Y.P	B.L. Tons	Elong %	R.A %	Fremont Test. "C" Nick. Kgm.	Angle.	"No" Nick Kgm.	Ang e.	Izod Test Ft. Lbs.	Angles.	Ball Test	Remarks.
									STEEL No. 3620.													
7	3620/T.94	.34	.14	.019	.018	.56	.71	3.57	850° Oil	—	85	110	1	1	5	4°	30	37°	18	3°	512 F. 512 I.	Fremont from Izod 6 × 4° 512
												Broke at shoulder										
8	,,	,,	,,	,,	,,	,,	,,	,,	850° Oil, 250° Air	—	84	112	11	34	9	5°	—	—	11	2°	477 F. 477 I.	Fremont from Izod 5 × 4° 477
11	,,	,,	,,	,,	,,	,,	,,	,,	850° Oil	36	100	128	1	4	4.6	2°	—	—	12	2°	600 F. 534 I.	
												Broke at shoulder										
12	,,	,,	,,	,,	,,	,,	,,	,,	850° Oil, 250° Air	64	106	115	14	49	5.3	8°	—	—	15	2°	477 F. 477 I.	
	3620/T.198	.35	.15	.012	.009	.58	.72	3.58	850° Oil, 200° Air	62	100	125	4	8	16.3	4°	—	—	14	1°	600 F. 555 I.	
									STEEL No. 3614.													
1	3614/P.60	.26	.20	.006	.031	.56	1.30	4.29	800° Air	—	94	106	3	4	—	—	—	—	9	2°	— 477 I.	
2	,,	,,	,,	,,	,,	,,	,,	,,	800° Air, 250° Air	—	90	106	1	5	—	—	—	—	20	4°	— 477 I.	

REMARKS.—Tempering at 250° C. appears to improve the shock qualities of both these steels in the 100 ton condition.

The increase in Elastic Limit and Yield Point of 3620 Steel is also remarkable.

All the above temperatures are in Centigrade figures.

Some of these steels are of patented composition and treatment.

EXPERIMENTS IN THE HADFIELD RESEARCH LABORATORY REGARDING THERMAL CONDUCTIVITY OF VARIOUS STEELS.

T 7594 B.

Forged Material

Compared in each case with forged normalised S.C.I., taken as 100.

(S.C.I. is Swedish Charcoal Iron of about 99.90% purity—Fe—as used in the Hadfield Experiments during the last twenty years.)

Steel No.	Analysis.							As Forged.	Normalised.		Special Treatment.	
	C.	Si.	S.	P.	Mn.	Cr.	Ni.	Conductivity.	Treatment.	Conductivity.	Treatment.	Conductivity.
1515	.20	.30	—	—	1.35	—	—	44	850 Air	49	850 Water 600 Water	56
3610	.37	.13	.039	.035	.93	—	—	53	830 Air	58	885 Oil 640 Air	55*
3004	.44	.21	.044	.032	.88	—	—	52	830 Air	55	885 Oil 640 Air	63
3386	.27	.25	—	—	1.50	.40	—	39	850 Air	39	850 Water 700 Water	45
3620	.37	.24	—	—	.47	.65	3.47	29	800 Air	33	650 Oil 675 Water	44
3197	.29	.08	.029	.038	.50	.78	3.50	27	800 Air	29	885 Oil 775 Furnace 615 Water	41
3612	.26	.22	.025	.025	.58	.84	3.67	29	800 Air	31	885 Oil 640 Air	39
1010	1.28	.14	—	—	12.73	—	—	17	—	—	1050 Water	17

* This figure is probably low. It is the average of four determinations between 40 and 63. Possibly the 40 was a wrong result and 61/62 is a more correct figure.

All the above temperatures are in Centigrade figures.

Some of these steels are of patented composition and treatment.

Dr. W. H. HATFIELD said he and his Sheffield friends had not come to criticise but to show their appreciation of General Bagnall Wild. When he first met him, in the early days of the war, there were practically no aeroplanes and the whole of the technical side of aeronautics had to be built up. General Bagnall Wild was still chief of the A.I.D., and it showed he had not only high personal traits, but great breadth of human feeling as he handled a staff of between six and seven thousand. The Sheffield manufacturers would have none but pleasant recollections of their dealings with him. The lecturer had a complete set of specifications to which the steel makers had worked with pleasure. A previous lecture by Major Philpot, on Notch Bar Testing,* contained a volume of data bearing on the safety of aero steels. It was a great thing for the manufacturers to find that the Government had as representatives men who fully appreciated the scientific principles underlying the manufacturers' work. He was very much interested in the Major's criticisms of welding. Some 18 months ago he (Dr. Hatfield) gave a lecture to the Society on steel used in aero work, in which he pointed out that welding should be avoided if possible. Tests of welds made under special conditions were misleading, as in the case of aeroplanes made in quantity one had to depend on the workmen. In the many welds he had examined he had found practically none free from those inclusions or oxides the lecturer had put on the screen. The future of aeronautics and automobilism would largely depend on the development of high tension steels.

Mr. WORTLEY FAWCETT said they were doing their best in Sheffield to get over the difficulties in producing perfectly good steel, and now the war was over they would be only too pleased to see any representatives of that Society and let them see the practical working—how steel was made and treated.

The CHAIRMAN, in moving a vote of thanks to Major Philpot, remarked that many of the photomicros were developed by the great Sheffield expert, Dr. Sorby. He was the first man to really apply the art of studying the structure and condition of steel. The illustrations shown to-night showed how much they were indebted to him. Dr. Hatfield made a remark about the workmen. They should try and educate the workman and assist him to rise. That was the best way to fight Bolshevism.

Major PHILPOT having acknowledged the compliment,

Major-General R. M. RUCK (President of the Society) proposed a vote of thanks to Sir Robert Hadfield, who he said was an eminent man of science and was equally known as a great manufacturer. They were very grateful for the invitation to visit Sheffield. The country appreciated very much the share the manufacturers had had in winning the war. The Society would be pleased to hear Sir Robert had promised to give the Society the greatest amount of assistance possible.

* "Some Experiments on Notched Bars." Proceedings of the Institution of Automobile Engineers, April, 1918.

SHOP PRACTICE IN RESPECT TO AIRCRAFT STEEL.

BY MAJOR H. P. PHILPOT, R.A.F.

Owing to the unfortunate illness of my chief, General Bagnall Wild, it has become my duty to give a lecture this evening at extremely short notice. I shall be under some difficulty in putting before you the information which he had intended to give you because a written lecture has not been prepared beforehand, and I have only had about a quarter of an hour's interview with him with the object of finding out what were his intentions.

I understand that the lecture was to be one for the Students of the Society, and that so far as the metallurgical part is concerned the language used should be, as far as possible, of an elementary nature.

We shall find it convenient to examine the changes which take place in a material in a more familiar condition, and gradually lead up to the consideration of the transformations which occur in a piece of steel when subjected to heat.

We will start by considering what happens in a liquid solution which is gradually frozen, and by analogy shall be able to show some of the changes which take place in the heat-treatment of steel during the different processes employed in the heat-treating workshop.

Imagine that we have a salt which is soluble in water but is entirely insoluble in ice, such as sodium nitrate, which is practically insoluble, and starting with a solution of that salt in water, proceed to cool it until it begins to freeze.

In Fig. 1 we have a diagram which shows the different stages which occur when solutions of different percentages of sodium nitrate in water are cooled gradually. The divisions on the line OX represent the percentage of nitrate dissolved in the liquid solution. The temperature of the mixture is shown by the divisions on the vertical line OY. It will be seen that at 40° C. a solution may have anything from zero up to about 49 per cent. of nitrate dissolved in it.

Now, according to the proportion of sodium nitrate in the water, the action of the solution in freezing differs. If we take a solution of about 37 per cent. of the salt in water and proceed to cool it gradually from a point A_2 at 40° C., it will cool down to — 18.5° C., when it will freeze out into a solid. The whole of the freezing takes place at the one temperature of — 18.5° C. The solid formed will be of a crystalline nature, but as the salt is insoluble in ice each crystal will be composite, and will be formed as a number of plates of the salt separated by plates of ice between them (see Fig. c_2 at the foot of the diagram). This solution is a liquid at A_2 and a crystalline solid at C_2 consisting of one type of crystal of laminated structure.

If, however, we start at A_1 with a weaker solution of nitrate in water, say 15 per cent., and cool it down from 40° C. at A_1, the freezing of the liquid will start at D_1 in a different manner to that of the 37 per cent. solution. When the temperature has fallen to the point D_1 freezing will begin, but this freezing will be selective and crystals of pure ice will be formed in the liquid solution. At a point B_1 the mixture will be partly ice and partly a solution of nitrate somewhat

stronger than the 15 per cent. solution with which we started. This will resemble a partly-melted ice cream, and may be described as being in a " mushy " state.

If the experiment is carried out at the earth's surface, the ice, being lighter than the water, will, under the action of gravity, rise to the top of the solution, and similarly in the case of the 45 per cent. solution, which will be considered later, the salt, being heavier than water, will sink to the bottom of the solution. In order that these complications may be eliminated, let us imagine that the experiments are being made in a space in which the attractions of gravity are balanced or eliminated, so that there is no tendency for the lighter and heavier parts to move relatively to one another. Under such conditions the solution would only be kept together in one mass by the internal attractions of the atoms and the surface tension of the liquid, and freezing would start at several points in the liquid. There would be no forces causing the crystals of ice, or of the salt, to alter their relative positions.

As the temperature is decreased, more and more ice is formed until at the point E_1 the temperature will have fallen to — 18.5° C. and the solution will now consist of crystals of ice surrounded by a liquid 37 per cent. solution of nitrate in water. With further cooling this remaining liquid freezes out into crystals of the same composition as were obtained from the 37 per cent. solution, each crystal consisting of plates of nitrate and ice. We get a composite structure, a mixture of crystals of ice with the laminated crystals between them, as indicated diagrammatically at c_1.

Now consider the cooling of a stronger solution, say 45 per cent. of nitrate in water. Starting as before from 40° C. at A_2, cool the solution gradually to the temperature represented by the point D_3. At this point the solution begins to solidify. The solids which now form, instead of being ice, will be nitrate, and we shall get crystals of nitrate formed in the solution which will become weaker than the 45 per cent. solution with which we started. Cooling this still further, we come to the point E_3 at the same temperature, — 18.5° C., as before. The remaining liquid has now become a 37 per cent. solution. If we continue to cool the mass, this remaining liquid will freeze out between the crystals of nitrate previously formed, and we will thus get crystals of sodium nitrate together with laminated crystals of nitrate and ice.

Starting with this type of liquid solution, we can get three types of solids by freezing liquid solutions of different strengths. The middle one, containing 37 per cent. of nitrate, is a most interesting one, because (1) it is the solid which melts at the lowest temperature, and for this reason is referred to as a " eutectic " solid (the word " eutectic " is derived from the Greek, and means " easy melting " or " well melting "); (2) the whole of the solid melts at one temperature of — 18.5° C., instead of melting progressively through a range of temperatures; (3) this solid will consist of crystals formed of plates of nitrate and ice; and (4) in the case of the two solids c_1 and c_3 the eutectic crystals will be the first to melt out of the composite mass. The diagram is called an equilibrium diagram because it shows the equilibrium conditions of the solutions at various temperatures. We start from the liquid solution at the upper part, and the diagram shows us how the solids are formed from the liquid. The solids are crystalline, and the crystals will show the different conditions from which we started. The line $FD_1D_2D_3G$ is called the " liquidus," because the whole of the material is liquid at any temperature above this line. The line HE_2K is referred to as the " solidus," because at any temperature below this line the whole of the material is solid.

A liquid solution is a condition of materials which is familiar to all, but we will now consider briefly an anologous condition in a solid. In a liquid solution any small portion which is separated from the bulk will be of exactly the same composition and will consist of exactly the same proportions of the solvent and of the dissolved constituent. In this respect a solution differs from a mixture,

such as a mixture of sand in water. The proportion of water and sand will vary throughout the mixture. If we have two solids which are mutually soluble in one another at a given temperature it is not very difficult to see that we can have a solid solution of one solid body in another. A glass of whisky and water has been described as a liquid solution, *i.e.*, whisky and water, contained in a solid solution, *i.e.*, glass, which is a solid solution of certain chemicals at atmospheric temperatures.

The conceptions given above will be useful in considering the equilibrium diagram of steel and cast iron (see Fig. 2). A pure steel or cast iron consists essentially of iron and carbon with other constituents which may be left out of the preliminary considerations of the subject and their effect taken into account later on.

The upper part of the diagram, Fig. 2, shows the transition from the molten metal above the lines FD_1E_2G which gives the "liquidus" of the iron carbon equilibrium diagram to the solid metal at the line FE_1HE_2K. This upper part of the diagram is of more practical interest to the steelmaker than to the steel user, and time will not permit of more than a passing reference. The resemblance between it and the diagram, Fig. 1, will be obvious, and it will be seen that the transition stages from the molten metal above FD_1E_2G to the solid metal below FE_1HE_2K is worth noting. The line FE_1H is curved because carbon in small proportions is not insoluble in solid iron at certain temperatures. The point E_2, about 4.3 per cent. carbon, corresponds to an eutectic condition of carbon and iron, but this is in the range of carbon contents which refers to the cast-iron series and not to steel.

A vertical line $A_1D_1B_1E_1C_1$ drawn for a particular percentage of carbon (say 0.5 per cent.) shows that the steel is molten at a point A_1 above the "liquidus." On cooling, freezing commences at the temperature represented by the point D_1. At a point B_1, between D_1 and E_1, the metal is partly molten and partly solid, and is in a "mushy" state. At E_1 the metal becomes solid, and at, say, point C_1, within the area $FE_1Hd_3d_2d_1fF$, the metal is a solid consisting of a solid solution of carbide of iron in iron. Carbide of iron is a combination of carbon and iron consisting of three atoms of iron with one of carbon, and is expressed in chemical symbols as Fe_3C. (The symbol Fe = ferrum, which is the Latin word for iron.) The solid solution of carbide of iron in iron is called "austenite."

The division between cast iron and steel is a conventional one, and the maximum carbon limit for steels may be considered arbitrarily as being between 1.5 per cent. and 1.7 per cent., as very few steels contain more than 1.5 per cent. of carbon.

The transformations which take place in the heating and cooling of a pure carbon steel are represented by the portion of the diagram between the vertical line OY and a vertical line such as LH at about 1.7 per cent. carbon, and the lines $fd_1d_2d_3H$ and $he_1e_2e_3K$. This part of the diagram may be referred to as the transformation diagram for solid steel, and gives the points at which certain transformations take place in the condition of a piece of steel when heated or cooled sufficiently slowly to allow of the complete change.

If a steel containing 0.89 per cent. of carbon is cooled from a temperature represented by the point a_2 it will be found that a change takes place at a temperature of about 700° C. near the point d_2e_2. Above this temperature the steel is a solid solution, but below it the steel consists of grains or crystals of laminated structure known as "pearlite." The laminations consist of alternate plates of carbide of iron and of pure iron. As this particular steel has in the transformation range properties very similar to those of a "eutectic" solid it is referred to as a "eutectoid" steel, because the transformations from the solid solution, or austenite, resemble those of a "eutectic" liquid solution to a "eutectic" solid.

Fig. 4 shows a microphotograph of a piece of carbon steel of about 0.9 per cent. carbon taken at a magnification of 300 and afterwards reduced to about × 210.

For a steel containing about 0.3 per cent. of carbon the vertical line $a_1d_1e_1c_1$ gives the critical temperatures or temperatures at which transformations take place. In this case, as the steel cools downwards from the austenitic or γ-condition at a point a_1, a change begins to take place at the point d_1 and some of the iron separates out of the solid solution, giving ferrite or pure iron, in the β-condition. This afterwards changes to what is known as the α-condition between the horizontal line at about 770° C. and hk, and finally at the point e_1 the remainder of the austenite separates into alternate plates of carbide of iron and of iron, *i.e.*, pearlite. At atmospheric temperatures the steel, after slow cooling, consists of ferrite, shown in Fig. 3 by the white patches, and pearlite shown by the dark patches in the same figure.

For a steel containing about 1.3 per cent. carbon starting at a_3 and cooling slowly carbide of iron, which is in this case known as "cementite," begins to separate out of the austenite in a similar manner to the separation of sodium nitrate from the 45 per cent. solution. Between d_3 and e_3 more and more cementite separates out until at e_3 the remaining austenite changes to pearlite. In Fig. 5 the white patches show cementite and the dark patches pearlite.

The three microphotographs, Figs. 3, 4 and 5, should be compared with the three sketches c_1, c_2 and c_3 at the foot of the diagram, Fig. 1. It will be seen that the transformations which occur in the steel resemble very closely those which take place in the freezing of the liquid solution of sodium nitrate in water. The ferrite corresponds with the ice formed in the 15 per cent. solution, pearlite with the eutectic solid, and cementite with the salt thrown out from the 45 per cent. solution. With steel we start from a solid solution, *i.e.*, austenite, in place of the liquid solution.

Fig. 6 shows a method by which the critical temperatures which occur in the transformations of a steel can be determined in order to enable the iron-carbon equilibrium diagram, Fig. 2, to be plotted. In this diagram the heating and cooling curves obtained from a piece of steel of about 0.25 per cent. carbon content have been plotted. The steel was first heated gradually and uniformly, and the time taken per degree rise of temperature has been plotted horizontally at each point on the temperature scale which is set out on the vertical line, giving the heating curve AB. It will be seen that the temperature rises at a uniform rate until the point C is reached, but that after this point is reached the time taken per degree rise of temperature rapidly increases, showing that the steel is absorbing heat without a corresponding rise of temperature taking place. This absorption of heat marks an internal change which is taking place in the steel. For a low carbon steel three such points, Ac_1, Ac_2 and Ac_3, occur with rising temperature corresponding with the points at which a vertical line, such as c_1a_1 in Fig. 2 cut the horizontal line hk at e_1, the intermediate horizontal line, and the inclined line fd_1 at d_1. If in a similar manner the time taken per degree fall of temperature when cooling is plotted horizontally in Fig. 6 we get the cooling curve DE, which shows similar points, Ar_3, Ar_2 and Ar_1, at which the fall of temperature is retarded owing to the reversed changes taking place in the steel.

The diagram, Fig. 2, refers to a pure carbon steel containing only carbon and iron. In commercial steels certain other constituents, of which the most important are manganese, nickel and chromium, are added, and have very distinct hardening effects on the steel and also the power of altering very considerably the physical properties. Such hardening constituents also produce a very marked "lag" in the positions of the critical points on the cooling curve, giving change points which do not occur at exactly the same temperatures as those which occur in the heating curve. The curves in Fig. 6 show a difference of temperatures for

the critical points on heating and cooling due in part to the presence of manganese.

An extreme case in which this lag is shown occurs in Fig. 7, which gives the heating and cooling curves for a steel containing about 0.9 per cent. carbon and 5 per cent. of nickel. In this case the critical point on the cooling curve occurs about 280 degrees below that on the heating curve. This fact can be made use of in the hardening of certain alloy steels which may, after being raised to the upper critical temperature, be allowed to cool somewhat before quenching, thus reducing the probability of producing quenching cracks.

Figs. 8 to 16 show photographs of a number of test pieces which were prepared by General Bagnall Wild several years ago which have been recently re-etched and photographed. Each of the specimens was first annealed by heating in a slag ball for about four days and cooling very slowly. The result of this treatment has been to produce in the body of the test piece a coarsened grain which when etched is visible upon the surface without the necessity of using a microscope. One end of each of the test pieces was then raised to the melting point while the other end was kept cool by water. The result of this further treatment has been that the piece of steel has been subjected to a variable temperature along its length, and evidence of the transformations which occur in the steel when heated to different temperatures are shown in the varying conditions of the test pieces (see Figs. 8, 9, 12 and 14). In each of these figures the upper end is the end which has been subjected to the highest temperature.

In Fig. 8, which refers to a low carbon steel of about 0.25 carbon, it will be seen that the structure below the line indicated by letters *AA* is fairly uniform. Line *AA* will correspond with a temperature of about 730° C., showing the beginning of the transformation of the steel, and it will be seen that above this line the dark portions representing pearlite become still darker, and then towards the top end are gradually diffused until they finally disappear below the part which has been overheated. The line *BB* would correspond with the upper end of the critical range.

Fig. 9 in a similar manner shows the changes which occurred in a test piece of medium carbon steel containing from 0.3 to 0.35 per cent. of carbon. Again the line *AA* corresponds to the lower critical temperature and *BB* to the upper critical temperature. Fig. 10 shows the beginning of the change of the pearlite and corresponds with line *AA* in Fig. 9. It will be seen that the pearlite loses its laminated structure. Fig. 11 is a microphotograph taken from a point near the line *CC* and shows the diffusion of the carbide in the ferrite.

Fig. 12 shows a test piece of about 0.9 per cent. carbon steel. In this case it will be seen that there is a very well defined line *AA* which indicates the transformation of this steel, and Fig. 13 shows a microphotograph taken just below this line. Fig. 13 is of particular interest in that it shows the change from laminar pearlite into granular pearlite which occurs just before the complete solution. This is commonly referred to as the "balling up" or "divorce" of the pearlite. A steel when in this condition would be very unsatisfactory in use, and particularly in the case of a low carbon steel should not be put into service.

Fig. 14 shows a test piece of high carbon steel with about 1.3 per cent. carbon content, and Fig. 15 is a microphotograph taken at a low magnification of about 30 (reduced to × 18 in the figure) from the same test bar covering the whole of the transformation range. The line *AA* corresponds to the lower critical temperature and *BB* to the upper critical temperature. At *AA* the pearlite dissolves and at the line *BB* the cementite is diffused. Fig. 16 shows the change point of the pearlite at a magnification of 300 (reduced to × 180). It will be seen here that the cementite is unchanged.

It will be clear from an examination of the photographs shown in Figs. 8 to 16 that a steel at atmospheric temperature can exist in many very different conditions

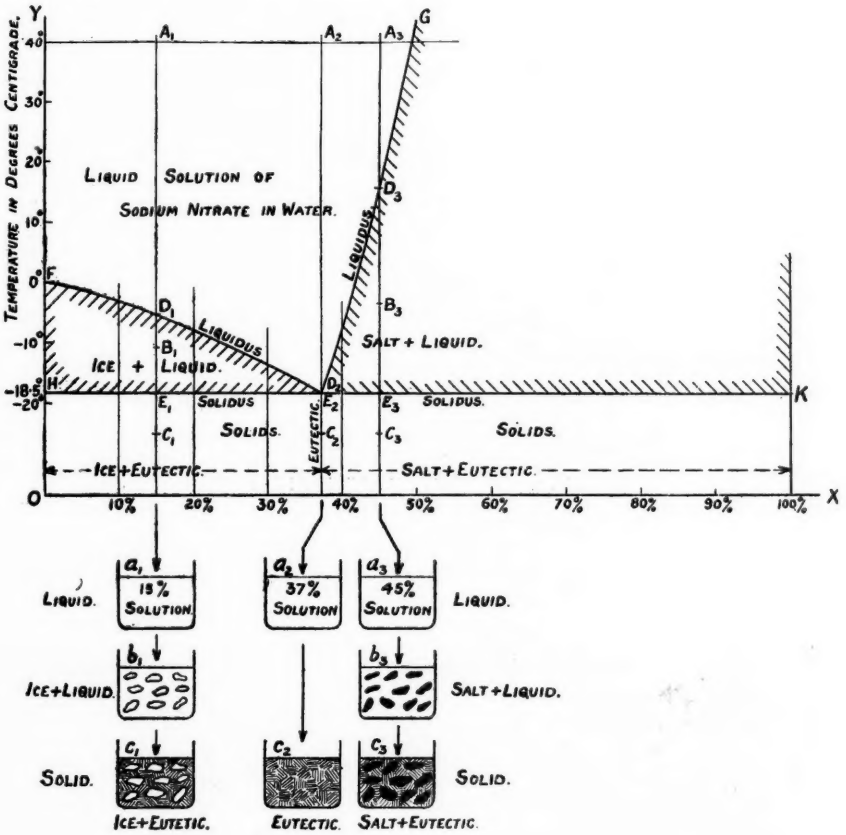

Fig. 1. Equilibrium Diagram of Solutions of Sodium Nitrate and Water.

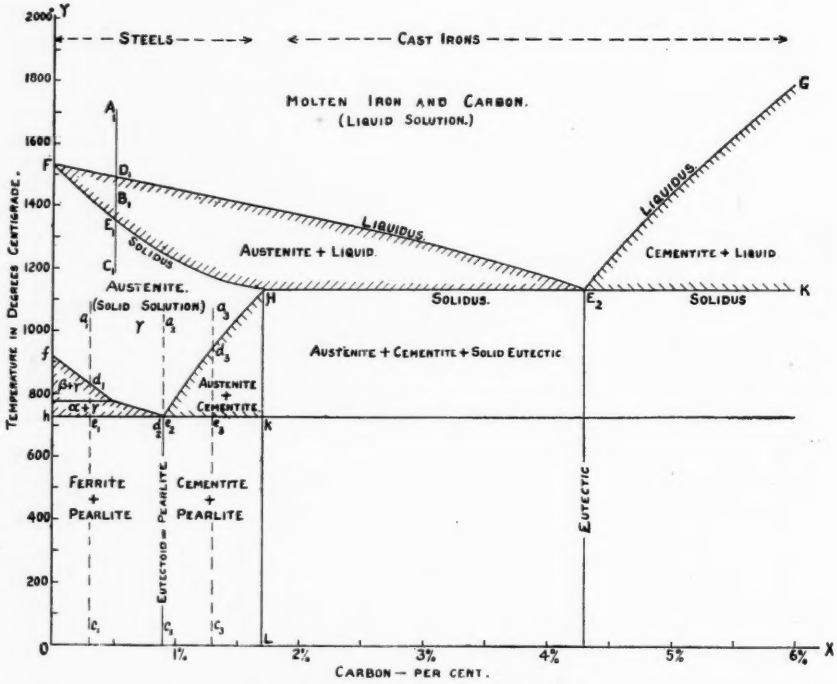

Fig. 2. Iron-Carbon Equilibrium Diagram.

Fig. 3.—Low carbon steel, cooled slowly, showing ferrite and pearlite. Etched, Picric Acid. ×210.

Fig. 4.—Carbon steel, about 0.9% carbon, cooled slowly, showing pearlite. Etched, Picric Acid. ×210.

Fig. 5.—High carbon steel, about 1.3% carbon, cooled slowly, showing pearlite and cementite. Etched, Picric Acid. ×210.

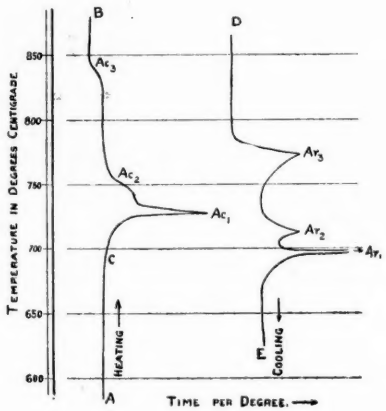

Fig. 6. Heating and Cooling Curves.

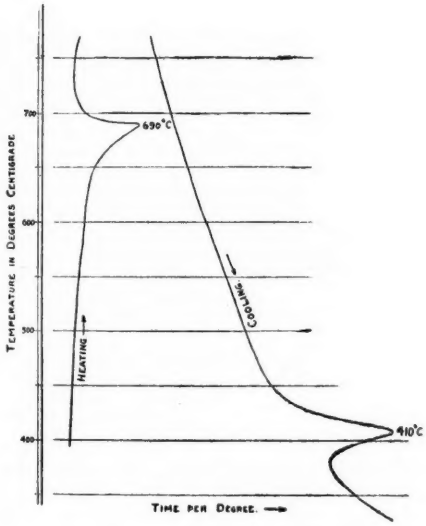

Fig. 7. Heating and Cooling Curves.

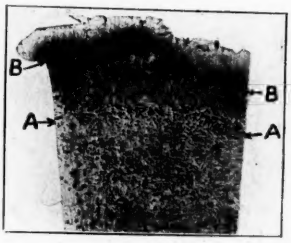

Fig. 8.—Low carbon steel, about 0.25% carbon. Etched, Picric Acid.

×1.5.

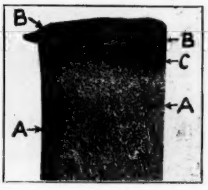

Fig. 9.—Medium carbon steel. Etched, Picric Acid. Full size.

Fig. 10.—Medium carbon steel at point A in Fig. 9, corresponding to the pearlitic change point. Etched, Picric Acid.

×160.

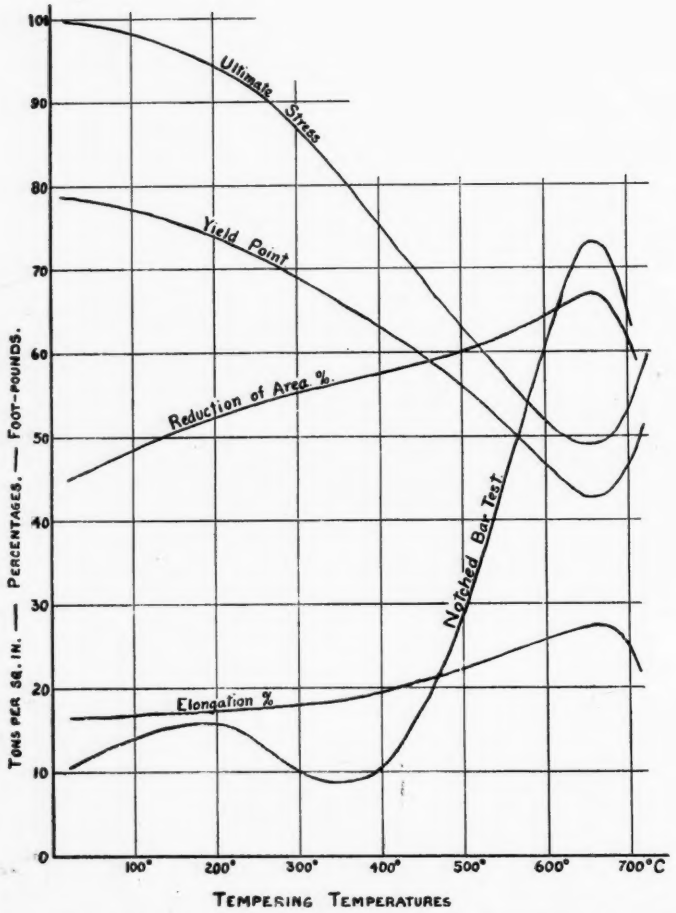

Fig. 17. Nickel Chrome Steel. Variations in Physical Properties, with varying Tempering Temperatures.

Fig. 11.—Medium carbon steel between points C and B in Fig. 9, showing diffusion of carbon in the ferrite at about 850° C.
×180.

Fig. 12.—Carbon steel, about 0.9% carbon.
×1.2.

Fig. 13.—Change point in 0.9% carbon steel, showing "balling up" or "divorce" of pearlite.
×180.

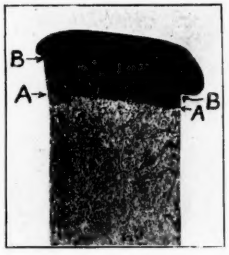

Fig. 14.—High carbon steel, about 1.3% carbon.
×12.

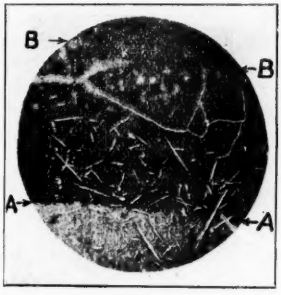

Fig. 15.—High carbon steel, about 1.3% carbon, showing diffusion of cementite.
×18.

Fig. 16.—High carbon steel, about 1.3% carbon, showing change of pearlite, cementite needles unchanged.
×180.

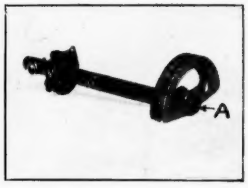

Fig. 18.—Dual control tube, broken near weld at point A.

Fig. 19.—Dual control tube, showing overheated structure of the steel near weld.
×160.

Fig. 20.—Structure of a thin tube near weld, showing liquation of the steel due to excessive temperature during welding.
×160.

Fig. 21.—Landing gear socket. Failure due to use of welded tube in a part subjected to circumferential stresses.

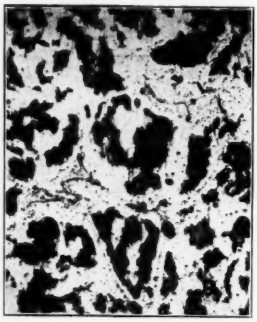

Fig. 22.—Hinge plate. Steel "burnt" in stamping. ×170.

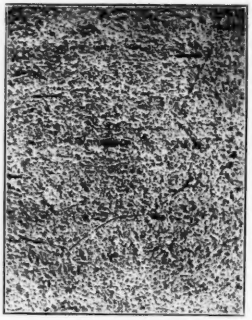

Fig. 23.—"Burnt" structure in a heat-treated steel brought out by prolonged etching. ×28.

Fig. 24.—Wrought iron used for lug on a seaplane. ×150.

Fig. 25.—Fold or lap in stamping. Etched with cupric reagent. ×5.

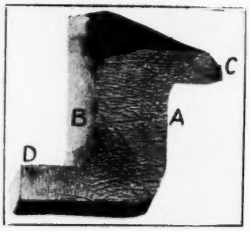

Fig. 26.—Macrostructure of arm of crankshaft which had been produced by machining from a forged and pressed slab. Etched with cupric reagent. Half size.

Fig. 27.—Crankshaft showing "fatigue" fracture starting from radius between journal and crank arm.

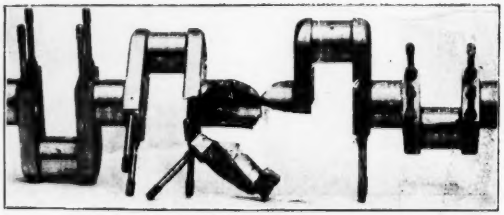

Fig. 28.—View of a broken crankshaft.

Fig. 29.—Broken crankshaft, showing "fatigue" fracture of one arm and subsequent fracture of second arm.

Fig. 30.—Slag and oxide inclusions in a broken crankshaft.

×170.

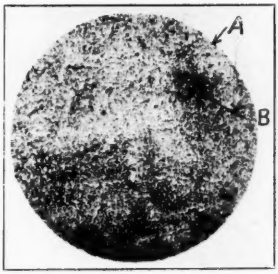

Fig. 31.—Structure of crankshaft, showing "fatigue" crack starting from a small inclusion.

×170.

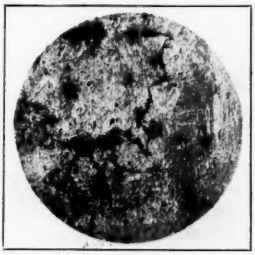

Fig. 32.—Structure of crankshaft, showing cracks following inclusions.

×160.

Fig. 33.—Haircracks in crankshaft, probably produced during forging.

×190.

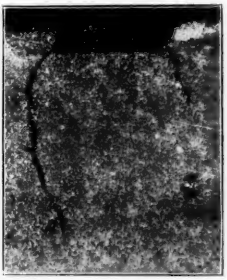

Fig. 34.—Broken crankshaft, showing cracks starting from sharp corners of keyway.

×3.

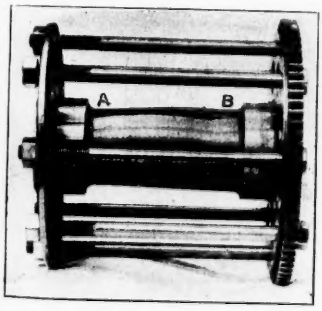

Fig. 35.—Failure of propeller boss. Key forced through side of boss at AB.

Fig. 36. Structure of a broken propeller boss. The steel had not been normalised or heat-treated in any way subsequent to forging.

×150.

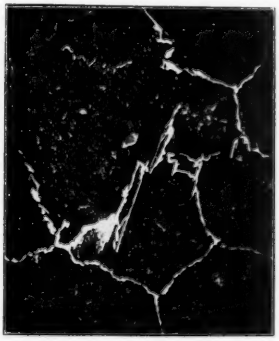

Fig. 37.—Cementite in case of a gudgeon pin.

×190.

Fig. 38.—Core of camshaft, showing free ferrite due to incorrect quenching temperature.
×190.

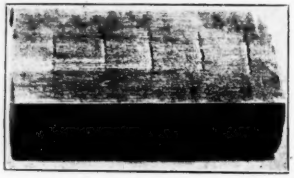

Fig. 39.—Bright drawn-steel bar, showing cracks produced in drawing process.
Half size.

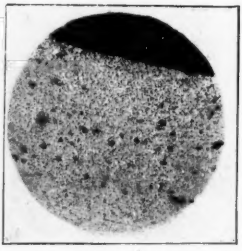

Fig. 40.—Broken wiring plate, coarse grained structure at bend due to annealing cold worked steel at too low a temperature.
×30.

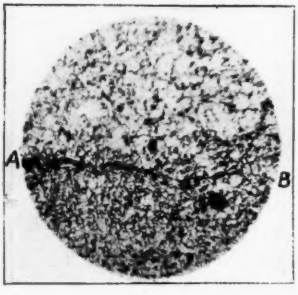

Fig. 41.—Broken wiring plate, showing crack AB along border of coarse-grained portion.
×180.

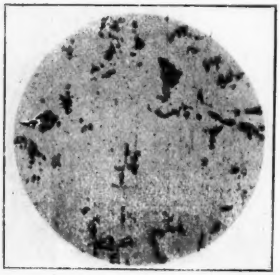

Fig. 42.—Broken bolt, showing "divorced" pearlite due to annealing at 670° to 680° C.
×180.

Fig. 43.—Rolling cracks in streamline wire.

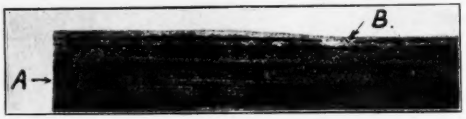

Fig. 44.—Streamline wire broken in flight, fracture due to cracks produced in rolling.

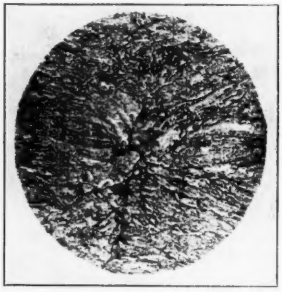

Fig. 45.—Internal cracks in streamline wire produced during rolling, due to segregation in centre of wire.
×160.

depending upon the temperatures to which it has been raised since it was first manufactured and upon the rate of cooling from these temperatures. Referring to Fig. 9, for example, below the line *AA* the steel is in the condition produced by prolonged annealing with very slow cooling. Between *AA* and *BB* the steel has been heated to a gradually rising temperature in the critical range and cooled quickly, while above *BB* it has been raised above the upper critical point and cooled quickly. Above *BB* the steel will be in the hardened state and below *AA* in its softened condition.

The process of hardening a steel consists in heating the steel to a temperature slightly above its upper critical temperature and cooling it in a suitable medium. This medium may be water, oil or air, according to the composition of the steel, or it may be in some cases a layer of oil on top of water if an intermediate condition between water and oil hardening is desired.

A piece of steel after being hardened may have its hardness reduced and its toughness and ductility increased by tempering at a suitable temperature according to the physical or mechanical properties desired. The tempering temperature should not reach the lower critical temperature, as if it does so the resulting condition of the steel will be variable and its physical properties uncertain.

Fig. 17 shows the variations in physical properties that can be produced by hardening a medium nickel chrome steel by quenching in oil from a temperature of 820° C. and then tempering at various temperatures. It will be seen that the ultimate tensile stress and yield are gradually reduced as the tempering temperature is raised, and that the elongation and reduction of area are gradually increased up to a temperature of about 680° C. The value obtained from the notched bar test first shows an increase at the lower tempering temperatures and then decreases, followed by a rapid rise with temperatures from 500° C. to 650° C. When the reheating temperature reaches the lower critical temperature for this steel the ultimate stress and yield increase and the elongation and reduction of area decrease and the notched bar value rapidly decreases. The steel should not be put into service in this condition as its physical properties will be variable.

It will be useful to consider some cases of failure of materials, as much may be learnt from them on the question of the treatment of steels.

Defects Produced by Welding.

Figs. 18 and 19 refer to the failure of a dual control lever due to the fact that no attempt had been made to restore the material in the neighbourhood of the weld at the point *A* (Fig. 18). Due to the overheating caused by the welding process, the structure of the material near the weld had become very coarse, as shown by the microphotograph. (Fig. 19.) A part which has been welded should not be put into use unless it has been heat-treated after welding. For parts built up from sheet metal or thin tubes of carbon steel a simple form of heat-treatment, *i.e.*, normalising, may be adopted. Normalising consists in heating the parts in a suitable furnace or muffle until the steel is raised to a uniform temperature slightly exceeding its upper critical temperature and cooling the part freely in still air. The temperature should not exceed the upper critical temperature by more than 50° C., and the parts when removed from the furnace must not be placed in a draught, nor may they be piled in a heap on the floor. In the former case the parts would be chilled by the draught and rendered variable, and in the latter case those near the centre of the heap would be softened or annealed by being cooled slowly.

The welding process may, however, produce defects in the steel which no heat-treatment can restore. In Fig. 20 a microphotograph of a thin tube near a weld is shown. The photograph shows signs of "liquation," or melting, of the steel at the grain boundaries, *i.e.*, the steel has been heated to a temperature above the "solidus" in Fig. 2 and has been irretrievably damaged, and is only

fit for the scrap heap. The black portions show parts which have been melted, and it will be noticed that melting has followed the crystal boundaries.

Fig. 21 shows a landing gear socket which failed owing to the use of a welded tube in a part which was subjected to loads producing a stress in the circumferential direction. Welded tubes should not be used for such parts.

Overheating or "Burning" of Steel.

Two microphotographs are shown in Figs. 22 and 23, in which a steel has been irretrievably spoilt during forging and stamping due to the use of excessive temperature. In Fig. 22, which shows a microphotograph taken from a hinge plate, it will be seen that there are a very large number of small dark spots running through the white parts of the photograph, *i.e.*, in the ferrite around the grain boundaries. These show signs of segregations, probably of oxides, produced at a high temperature. Steel in this condition cannot be restored by heat-treatment.

Fig. 23 shows a microphotograph of a steel stamping which had been burnt. The steel had been subsequently heat-treated. The structure has in this case been brought out by prolonged etching, and the thin black lines show the crystal boundaries which existed at the time of burning. The heat-treatment has masked the evidence of the previous overheating, but has not eliminated the defect.

Use of Wrong Material.

A broken lug from a seaplane was shown by the microphotograph, Fig. 24, to have been made from wrought iron, in place of the mild steel intended by the designer. The trouble in this case is probably due to mixing in the stores or during transit. This case, and many similar incidents which have occurred, emphasises the great importance of some early and permanent marking of all metals for identification purposes, and also the necessity of very careful organisation of the stores if similar cases are to be prevented from occurring. If the material is marked before it leaves the original manufacturers and full particulars of all marking is sent to the consignee in time to reach his works before the material, a very prolific source of trouble should be eliminated, as the storekeeper would not be tempted to accept a wrong consignment when offered by the railway company. This has been known to occur, and is a possible explanation of Fig. 24.

Defects Produced During Stamping.

Fig. 25 shows a low-power magnification ($\times 5$) of a fold produced during the stamping process. This sample has been etched with a cupric reagent which brings out very clearly the flow lines of the metal produced during forging.

Macroscopical Examination.

The method which has been employed in the manufacture of a part can in many cases be discovered by etching cross-sections of the part with a cupric reagent. The manner in which the steel has been worked down from the original ingot can frequently be determined. One case of the use of this reagent has already been given in Fig. 25. Fig. 26 shows a section, approximately half size, cut from a crankshaft. This crankshaft has been cut from a forged and pressed slab, and evidence of this fact is given by the horizontal lines of flow of the metal at right angles to the crank arm at AB and along the journal at C. Towards the outer edges of the width of the slab at D it will, however, be seen that the flow of the metal sideways under pressure when widening the slab has changed the direction of flow in the crankpin to a direction perpendicular to the axis of the crankshaft.

Failures of Crankshafts.

Fig. 27 shows a well-defined example of the progressive failure of a crankshaft by so-called "fatigue." A small crack starting at the radius between the journal and the crank arm has gradually developed from this point as focus, showing well-marked lines of arrest in the fracture, until the metal remaining beyond the crack has been insufficient to support the loads and has finally broken through. This last part of the fracture generally shows an entirely different appearance to that of the "fatigue" fracture.

Fig. 28 shows a case of a spiral fracture around a crankshaft journal. The fracture in this case is a remarkable one, as the journal has broken through in both spiral and longitudinal directions.

In Fig. 29 we have a case of a "fatigue" fracture of one arm starting from the radius between crankpin and crank arm, followed by a complete fracture of the second arm. This fracture of the second arm shows quite clearly that it has taken place in an entirely different manner to that of the first arm. It is certain that it took place due to shock following the first breakage.

The fact that a very large proportion of crankshaft failures occur at the radii between the crank arm and the pins and journals constitutes a warning to the designer that such corners should be most carefully considered and as large a radius as possible should be adopted. If a small radius is used and happens to be combined with a steel defect or improper heat-treatment of the shaft the combination is extremely likely to lead to failure, even though the radius would be a reasonable one if everything else were right. In some cases a fatigue crack starts from a small groove left by imperfect machining of the part.

Figs. 30, 31 and 32 show microphotographs taken from three broken crankshafts in which the failures were due to defective steel.

Fig. 30 shows a bad case of slag and oxide inclusions in the steel.

In Fig. 31 the steel is found to have a number of small inclusions, two of which will be seen in the neighbourhood of the arrow *A*. From the right-hand end of the lower of these two inclusions it will be seen that there is an incipient crack starting, and leading downwards at an angle of about 30 degrees with the horizontal towards the point *B*. Once such a crack has started it will be quite easy to see that there will be concentration of stresses around the boundaries of the crack leading to a gradual increase in its dimensions. It will also be realised that the crack is started in the first instance by such concentration of stress, due to the existence of the original inclusion.

Fig. 32 shows a case in which there has been considerable development of a crack joining a number of inclusions. Towards the right-hand side of the photograph the crack shows several branches which have apparently developed at different times along lines of weakness caused by the existence of colonies of small inclusions in the steel.

Great difficulties have been caused during the war owing to the large number of cases in which small defects which have generally gone by the name of "hair cracks" have occurred in steels for different parts, and more particularly in crankshafts. These cracks have in most cases been traced to or ascribed to defects in the steel ingots, but in some cases they appear to have been caused during the forging operations. Those shown in Fig. 33 were found near the radius between the crankpin and crank arm of a crankshaft.

Fig. 34 deals with the failure of a crankshaft in which cracks have started from the sharp corners at each side of the keyway.

Failure Due to Omission of Heat-Treatment.

The omission of any form of heat-treatment of the steel was the primary cause of failure of the propeller boss shown in Figs. 35 and 36. It will be seen in Fig. 35 that the key has been forced through the side of the boss, causing the burst shown at *AB*. An examination of the material gave the structure shown in Fig. 36. The steel is in the condition in which it was left after the forging operations, and has not been normalised or heat-treated in any way.

Case-Hardened Parts.

Two cases of failure of case-hardened parts are illustrated in Figs. 37 and 38.

Fig. 37 shows a microphotograph of the cemented case of a gudgeon pin. This pin had been over-cemented, due either to the use of a cementing medium which was too powerful in its action or to the cementing process being too prolonged. The white lines, showing free cementite, are evidence that the carbon content of the case has been increased beyond the saturation point. The case when in this condition is liable to crack and flake off.

Fig. 38 shows the core of a camshaft. The white patches show free ferrite due to quenching at an incorrect temperature. The core has not been refined owing to the fact that the quenching temperature was too low.

Defects in Cold-Worked Steel.

From the point of view of production in automatic machines, cold-drawn bars possess very considerable advantage, but it should be remembered that the increased strength produced in the direction of cold drawing is only in part permanent, and there is a tendency for the strength to decrease with age. The cold drawing is also liable to produce defects in the bar which were not previously there. One type of defect is illustrated by Fig. 39. A cold-drawn bar about 1⅜in. diameter was being machined for test when it was discovered that the centre of the bar had been torn apart at practically regular intervals of about 9/16in. If this bar had been turned down in a lathe to about 1in. to 1¼in. diameter it would have fallen to pieces, as it was held together by an outer cylindrical portion about ⅜in. thick.

Cold working in another form combined with incorrect heat-treatment was responsible for the defect dealt with in Figs. 40 and 41. In this case a wiring plate had been produced by bending sheet metal to the desired form and then an attempt had been made to normalise the part. In the normalising process too low a temperature has been used, with the result that certain parts in the thickness of the plate which during the bending operation had been subjected to a stress within a certain critical range show a very considerable increase in the size of the grain. In the microphotograph, Fig. 40, at a magnification of 30 this variation of grain size is evident for a depth of about 0.3in. from the upper edge in the photograph representing a depth of about 1/100in. in the original plate. In the second photograph, Fig. 41, it will be seen that a crack has developed along the line *AB* at the border of the coarse-grained portion. A low carbon steel is subject to this increase of grain size if it is stressed or strained within certain limits, and is then heated to a temperature of about 650° C. This is one of those cases in which much more harm is done to the steel by heating to a temperature below the critical range than if the temperature is raised above that range. The part should have been heated to about 870° C.

Another case in which the temperature used has been too low is shown in Fig. 42, which shows "divorced" pearlite caused by heating to about 670° C. to 680° C. The sample in this case was a broken bolt made from a bright drawn-steel bar which had evidently been annealed at a temperature just below the lower critical temperature.

Another set of troubles which unfortunately are not among those against which we are warned and which "never happened" is illustrated by Figs. 43, 44 and 45. In the manufacture of streamline wires a bright drawn rod is rolled down to an oval section for the greater part of its length. The oval section is about half the area of the original round wire. This is a process which only steels of the very best quality are able to stand up to. Unfortunately, even when the steel is satisfactory, the workman is much too liable to look upon the process as one which is governed by the power of his machine, instead of by the limit which the steel can reasonably be expected to withstand, and at times an excessive pressure is used with the object of reducing the number of passes required to produce the desired effect. Fig. 43 shows the result which is likely to follow such excessive pressure. This result is a satisfactory one in that there is no likelihood of the wire getting into service, but if the resulting crack is very much less pronounced there is some danger of it being overlooked. Fig. 44 shows such a crack in a streamline wire which had broken in flight. It will be seen that in this case there is a fine crack running from the point *A* along the centre of the wire and turning outwards to the edge at the point *B*. The fracture which occurred in another part of the wire had apparently been caused by a similar fault. Such defects are not, however, in all cases attributable to the workman and his rolling machine, as is evidenced by the internal cracks shown in Fig. 45. In this case the defect is to be attributed to carbon segregation in the centre of the wire.

In conclusion, I wish to express my indebtedness to General Bagnall Wild for the loan of many very interesting slides, and to my assistants, Lieutenant W. E. Williams and Mr. Boursnell, who have produced some of the slides shown at very short notice.

ABSTRACTS.

Outline of History of Aviation Engine Production.

About the time of the American declaration of war a commission was sent abroad to make extensive investigation into the manufacture of internal combustion engines. The best high powered engines were considered to be the Rolls-Royce and Loraine Dietrich, the former not adapting itself to American methods of manufacture, and the latter not being completely demonstrated or accepted at the time. It was decided to design a distinctive American engine (the " Liberty ") developing approximately 200 h.p. with eight cylinders and 300 h.p. with 12 cylinders.

In August, 1917, the author was put in charge of the production department, and the real work of producing aeronautical engines begun. These fell into three headings :—

1. *Elementary Training.*—Curtiss OX. 90 h.p., A—7—A, 4-cylinder 100 h.p., and the Hall-Scott.
2. *Advance Training.*—Gnome 110 h.p., the Le Rhone 80 h.p., and the Hispano-Suiza 150 h.p.
3. *Combat.*—The only one available for American manufacturing purposes was the " Liberty."

Development of Liberty 12.

The Liberty 12-cylinder engine was originally designed to produce approximately 330 h.p., weighing 765 lbs. without water and oil. By readjusting parts the engineers stepped up the h.p. to 375, with the result that certain of the parts would not stand the strain, notably the crankshaft, and production was consequently delayed. In the summer of 1918 an increase of power up to 400 h.p. was required, and the engine was re-designed, giving approximately 440 h.p. with a weight of 860 lbs. The resulting strain placed on all the parts of the engine was too great, and it became necessary to enlarge and strengthen crankshafts, connecting rods, bearings, etc., etc., together with adjacent parts. The metallurgical specifications had to be changed with corresponding modifications in the methods of the steel mills, and in increasing the size of the parts all jigs, tools and fixtures in the machine building plants, the parts factories, forging shops, etc., were rendered obsolete, and new equipment had to be designed.

The changes in the engine arranged themselves into three groups.

(*a*) *Design.*—In this there were but two changes. One was the oil system which was changed from so-called scupper feed to forced feed, the latter system being fool-proof, and the other was an alteration in one part of the connecting rod to allow the rod sufficient play without cracking.

(*b*) *Increase of Power.*—On two occasions. These were the results solely of the demands of the aviation authorities.

(*c*) *Manufacturing Limits.*—These are of the usual type.

The best known engine comparable with the Liberty is the Rolls-Royce, the most prominent English engine. This developed 100 h.p. less and weighed equivalent to 100 h.p. less than the Liberty.

In the month of October more Liberty engines were produced than the total production of engines in England and France for any month during the four years of war. (H. H. Emmons, " Aerial Age Weekly," Dec. 9, 1918.)

L-W-F Model G-2 Fighting Aeroplane.

The author, who is the chief engineer of the L-W-F Engineering Co., claims that the G-2 type is one of the most successful of American two-seater tractor aeroplanes. Its general characteristics may be judged from the following details:

Overall width: 41 ft. 7½ in.
,, length: 29 ft. 1¼ in.
,, height: 9 ft. 4⅜ in.
Tread of wheels: 5 ft. 4 in.
Wheels: 26 in. × 4 in.

Wing cure, L-W-F No. 1 (modified R.A.F.6 with less camber), upper and lower wings.

Incidence: Lower wing, 0°; upper wing, +1°.
Decalage, 1°. Chord 80 in. upper and lower.
Dihedral, 0°. Gap 72 in., nose to nose on vertical line with body horizontal.
Backsweep, 0°. Stagger 7⅛ in. (positive).
Span: Upper wing, including ailerons, 41 ft. 7½ in.; lower wing 38 ft. 5¾ in.
Aspect ratio: Upper wing, including ailerons, 6.3; lower wing, 4.78; average, 5.54.
Total supporting area (including ailerons), 515.54 sq. ft.
Net area of main wings (not including ailerons), 465.46 sq. ft.
,, upper wings (including ailerons), 268.78 sq. ft.
,, lower wings, 246.76 sq. ft.
,, upper wings (not including ailerons), 218.70 sq. ft.
Total area of one aileron, 25.04 sq. ft.; balanced area, 1.95 sq. ft.
,, both ailerons, 50.08 sq. ft.
,, one elevator, 13.85 sq. ft.; balanced area, 1.5 sq. ft.
,, both elevators, 27.70 sq. ft.
,, rudder, 12.65 sq. ft.; balanced area, 1.31 sq. ft.
,, horizontal stabiliser (both sides), 29.15 sq. ft.
,, vertical stabiliser, 5.21 sq. ft.

Controls and Control Surfaces.

Dual stick control. Aileron wires enclosed in wings. Horizontal stabiliser double camber with centre line set at 0° to thrust line.
Elevator curve included in stabiliser curve.
Aileron curve included in wing curve extended.
Rudder and vertical stabiliser flat.

Power Plant.

Liberty 12-cyl. engine, direct connected, 435 h.p. at 1,700 r.p.m.
Air screw, 2-blade, tractor, diameter 9 ft. 7 in., average pitch 7.38 ft.
Propeller turned 1,800 r.p.m.

Weights.

Case 1.—Weight of complete machine (empty with gun mounts, but no guns), 2,675 lbs.

Case 2.—Equipped as a fighter:—

Weight, light	2,675.5 lbs.
90 gal. gas	553.5 ,,
14 gal. water	118 ,,
6 gal. oil	44 ,,
Ammunition	150 ,,
7 machine-guns	152 ,,
2 men	330 ,,
Total full load	4,023 lbs.

Case 3.—Equipped as a bomber:—

Weight, light	2,675.5	lbs.
120 gal. gas...	752	,,
6 gal. oil	44	,,
14 gal. water	118	,,
Ammunition	150	,,
7 machine-guns	150	,,
Armour	66	,,
4 bombs, rack and release	592	,,
2 men	330	,,
Total full load	4,879.5	lbs.

Loadings (based on 515.54 sq. ft. area and 435 h.p.).

Case 1.—Loading per sq. ft.	5.185	lbs.
,, ,, horse power ...	6.15	,,
Case 2.— ,, ,, sq. ft.	7.82	,,
,, ,, horse power ...	9.25	,,
Case 3.— ,, ,, sq. ft.	9.47	,,
,, ,, horse power ...	11.22	,,

Performance.

High speed at 10,000 ft. ... 130 m.p.h. (loaded as in Case 2).
,, at low altitude ... 138 ,, ,, ,,
Low speed (landing) ... ... 50 ,, ,, ,,

Climb: Case 1.—10,000 ft. in 7 min. 28 sec.
,, ,, 2.—10,000 ft. in 9 min. 18 sec.
,, ,, 3.—10,000 ft. in 14 min. 45 sec.

Endurance.

Four hours at full speed. (G. D. Mitchell, "Aviation," Dec. 1, 1918.)

German Twin-Engined Bombers.—Gotha G.V. and G.V.a.

The article points out the differences between the Gotha G.V. and the G.III., described in "L'Aerophile" of Feb. 1-15, 1918.

There is a slight decrease in span, a slight increase in the chord of the wings, and the wing area is somewhat less. Ailerons are fitted to both planes, but only those of the upper are balanced and project beyond the main wing tips. The construction of the wings is identical with that of the wings of G.III. The interplane struts are steel tubes, and are streamlined by means of wooden sheaths.

The fuselage of the Gotha G.III. consists of longerons and wooden frames, covered with fabric; but in the G.V. plywood is employed as a covering. Two large tanks occupy the whole width of the fuselage where the wings are attached. In front of these tanks are two seats, side by side, one for the pilot and one for a passenger who has easy access to the machine-gun pit right forward. The machine-gun pit behind the tanks is isolated from the other two seats.

The motors are two 260 h.p. Mercédès as in G.III., but the engine nacelles are lightened and their resistance reduced by substituting a steel tube structure for the former erection of wood and steel, and fairing off neatly with metal sheets.

The rubber cord shock absorbers for the under-carriages have been replaced by spiral springs located within the tubular struts.

G.V. was designed to carry fuel sufficient for a flight of $7\frac{1}{4}$ hours at normal bombing heights.

G.V.a differs mainly in the fitting of a biplane tail, a feature now common to all large German machines. In the G.V.a also the area of the alierons has been

extended by adding a narrow piece along the trailing edge of each aileron. ("L'Aerophile," Nov. 1-15, 1918.)

Loening's Monoplane.

This two-seater is said to develop 145 miles per hour with full military load, including 4 guns, and to have a ceiling of 25,000 ft. with two passengers. It is equipped with a 300 h.p. American-Hispano engine. For the purposes of production, its design has been exceedingly simplified, requiring only one-tenth the number of parts of the ordinary European design. The wire stays have been eliminated and the monoplane structure strengthened without the loss of its advantage in speed. In official trials it climbed 10,000 ft. in 8 minutes. It carries practically double the load of the latest Sopwith and Spad machines with an even greater climbing speed. For the pilot the visibility is so improved by the wings being mounted on a level with the pilot's eyes that there are practically no blind spots. The machine has a speed range of over 100 miles per hour, carries the heaviest load per sq. ft. that has ever been successfully carried, and yet has a low landing speed. Its span is 32 ft. with a 7 ft. chord, and it weighs 13,000 lb. The body is deep and constructed of veneer bulkheads, like the hull of a torpedo boat destroyer. The wings are of the usual wood construction and the large bracing struts a combination of steel tube and wood. A novelty of the machine is the fastening of the wing to the top longeron of the body. ("Air Service Journal," Dec. 14, 1918.)

Hispano-Suiza Aeroplane Engines.

Four models, designated as A, I, E and H, are stated to have been produced in the United States. After pointing out the main differences between the various models, some account is given of Model I, which is described as typical of the entire series.

Model I is a fixed cylinder, water-cooled engine with eight cylinders, arranged in two blocks of four, which are set at an angle of 90°, the engine developing 150 h.p. at 1,450 r.p.m. at sea-level. It has a bore of 120 m.m. and a stroke of 130 m.m., and is the same as Model A except that it has the new straddle fork type of connecting rod, a different magneto drive and timing, and some slight modifications in the piston mounting. Its compression ratio is 4.72 to 1. Model E is more powerful, developing 180 h.p. for an additional 300 r.p.m., and a compression ratio of 5.33 to 1; while Model H, which has a bore of 140 m.m. and a stroke of 150 m.m., develops 300 h.p.

The general characteristics and two sectional diagrams of Model I are given. The new straddle fork type of tubular connecting rod is made from heat-treated steel, being forked at the bottom and bolted to a two-piece bronze box lined with babbitt, two bolts being used at each side. The bronze box bears directly on the crankshaft, and the other connecting rod bears on the outer and central portion of the bronze box, the shaft itself working between the forked ends of the straddle rod. Attention is also drawn to the cast aluminium pistons, $\frac{3}{8}$ in. thick at the head tapering to $\frac{1}{8}$ in. at the bottom; to the overhead cam shafts and the lack of rocker arms to the valves; to the double eight-cylinder magnetos; to the pressure lubrication system; to the single Strombery carburetter; to the fuel system; and to the water pump capacity of 100 litres per minute, at an engine speed of 1,450 r.p.m. ("Aviation," Dec. 1, 1918.)

Problems of Crankshaft Design.

This paper is confined to a study of the effect upon crankshaft design of the three most important groups of forces:—The pressures due to the gaseous mixture, the inertia forces, and the centrifugal forces. The smooth running and the life of the engine depend mainly on these three factors. The reciprocating

masses linked to the crankshaft are considered as one mass concentrated at a point in the axis of the cylinder, and the inertia forces due to the angularity of the connecting rod are treated in the usual way.

As subjects for investigation, medium size, six and twelve-cylinder engines, both of the same cylinder volume and speed, 2,700 r.p.m., are chosen. Both engines are supposed to be similar in design and up to the same standard of construction, except that the six-cylinder engine is a vertical engine and the twelve-cylinder of the V type, with an angle of 60°. Diagrams giving centrifugal forces and combined gas and inertia forces due to a single cylinder acting on the crankpin for two revolutions—one complete cycle in the case of four-stroke cycle engines—show that these forces are much smaller in the twelve-cylinder, although quite analogous to those in the six-cylinder engine.

In the case of the twelve-cylinder engine, two single-cylinder engines act on one crankpin, and therefore, to get the resultant force on the crankpin, the forces due to each engine mutually inclined at 60° were added vectorially. Two diagrams giving the resultant force on the crankpin in the two cases show that the difference between the loads is not marked. The maximum in the case of the twelve is 4,040 lbs., and in the case of the six 4,800 lbs.

It is difficult to neutralise the effect of these forces by balance weights owing to the effect of the connecting rod, and although it is feasible in the case of the six-cylinder engine, it is almost impossible for the twelve. The diagrams reveal the fact that the forces are smallest in a horizontal direction, suggesting that the oil holes in the crankpin should be placed at right angles to the crank.

The design of the bearing is discussed with relation to the bearing pressure, mention being made of both Professor Goodman's and Beauchamp Tower's research works. To estimate the heating of the bearing, the rise in temperature is taken as a function of the work expended in friction, other things being supposed unaltered. The work expended in friction per second and per sq. in. of bearing surface is given by

$$\omega = pv,$$

where :—

ω = coefficient of friction;
p = specific bearing load, lbs. per sq. in.;
v = circumferential velocity of shaft, ft. per sec.

Guldner states that for stationary engines with white metal bearings, pv should not exceed 1,500 ft. lbs. per sec., but for well designed gas engines with forced lubrication a value not exceeding 17,000 ft. lbs. per sec. is permissible. In the cases given, $pv = 16{,}900$ ft. lbs. per sec. for the six-cylinder engine with a crankpin 2 in. long and $2\frac{1}{8}$ in. diameter, and 16,800 ft. lbs. per sec. for the twelve with a crankpin of the same diameter and 1-5/32 in. long per engine, or a total length of 2-5/16 in. These figures are for the average force during the cycle. In practice a twelve-cylinder engine runs slightly faster than the six, in which case the difference in crankpin length would be more pronounced, but the twelve-cylinder engine is superior to the six as regards maximum pressure. On the uphill runs at slow speeds the pressure is mainly due to the high explosion, but is nevertheless smaller than the average at high speed.

The design of the main bearings of a seven-bearing type is next considered. Two groups of diagrams are given, viz. :—(*a*) Main bearing load without balance weights, bearings I. and VII., bearings II., III., V. and VI., and bearing IV. (*b*) Main bearing load with balance weights, the diagrams being for the same groups as in (*a*). Although the average pressure is less with balancing, and a balanced shaft runs steadier than an unbalanced one in a balancing machine, the sudden fluctuations produced by the reciprocating masses are such as to counteract these advantages.

For the twelve-cylinder engine the bearing surface for the main bearings works out to about 15 per cent. greater than those of the six.

A rough estimate of the crankpin strength to resist the torque, etc., gives a safety factor of about 12 in the case of the six-cylinder engine where the maximum torque is about two and a half times the mean, but is as great as 20 for the twelve where the maximum torque is only 50 per cent. greater than the mean. The greatest trouble is the design of the crank cheek, which is calculated to be 15/16 in. for the six and 7/8 in. for the twelve-cylinder engine.

The two cases of three and seven-bearing shafts are next compared. Since the distance between the bearings in the former case is about two and a half times that of the second, and that the transverse deflection of a straight shaft varies as the cube of the length, it follows that in the case of the three-bearing shaft the deflection will be of the order of sixteen times that of the seven. The deflection due to the torque is 1.3 times that in the seven-bearing shaft. These defects cannot be overcome by stiffening up, but might be obviated by balance weights.

On discussing the explosive pressure of the engines, the total piston displacement for different engines is proportional to the cube of the bore with a constant stroke-bore ratio, and the explosive impulse is taken proportional to the square of the bore. Thus, for equal total piston displacement, the explosive impulse is about 1.5 times as large in the six as in the twelve-cylinder engine.

In conclusion, it is stated that to obtain satisfactory conditions, the oil supply to the bearings must be proportional to the work converted into heat. (Burkhurdt, "Aerial Age Weekly," Oct. 28, 1918.)

Working Process of Internal Combustion Engines.

It is implied in the text that this article is to form one of a series upon the subject. In the present instance a short historical survey is given of the development of internal combustion engines from the Lenoir engine to the Otto, Otto free piston, two-stroke cycle, and the Diesel engines of the present day. The cycles and the causes of heat losses, etc., are briefly discussed and illustrated by sketches of indicator diagrams. A review of the development of efficiency with time shows an increase of efficiency from 12 per cent. in 1878 to 34 per cent. in 1916 for the four-stroke cycle gas engine, and 26 per cent. in 1897 to 39 per cent. in 1918 for the Diesel. The comparison is based on the gas consumption per effective horse-power. In future contributions a study of the nature of the fuel utilised, the real process of combustion, and the experimental data on hand concerning it will be given. (E. H. Sherbondy, "Aerial Age Weekly," Nov. 25, 1918.)

Lateral Stability in Aeroplanes.

This article attempts to analyse the function of the dihedral angle in producing lateral stability in aeroplanes. The author does not mention or accept the reasoning usually given, but attributes the stabilising effect to a righting moment brought into play, as he considers, when the machine is rolled about the direction of flight. Since the lift on each wing is the same whatever the angle of roll, it follows that the resulting moment is zero. The moment given in the article is the moment of the two vertical components of the lifts on each wing, and is equal and opposite to the moment due to the horizontal components. The generally accepted theory states that a moment is produced through side-slipping, not through the angle of roll. (C. Levick, "Aerial Age Weekly," Dec. 9, 1918.)

Corrosion Prevention on Aircraft Metal Parts.

For iron and steel parts on aircraft, corrosion is stated to be best prevented by painting or by galvanising. For the latter the zinc should be preferably

deposited up to a minimum thickness of 0.60 oz./ft.^{2} using the hot dip process, except for certain specially heat-treated steels or alloys, when the zinc plating process (cold galvanising) should be employed. Subsequent to plating an enamel or paint should be applied. Phospheric acid treatment or coating by tin or with tern plate are not considered desirable, because the salt process test shows marked corrosion within 5 to 24 hours compared with zinc-coated samples, which should be unaffected after 100 hours' continuous exposure.

To protect aluminium parts, "Spar Varnish" and "Naval Grey Enamel" are said to be very efficient. On Venturi tubes a thickness of approximately 0.0002 in. of Spar Varnish is recommended. (H. A. Gardner, "Aviation," Dec. 1, 1918.)

The Metal Airscrew.

A rough comparison between the respective merits and defects of wood and metal propellers is made in this article by the author, who has served as a captain in the Russian Army on the Eastern Front, and who claims that three out of seven metal airscrews which were made to his design operated successfully in service for over two years (1915-1917).

In the article attention is drawn to many of the known defects of wooden airscrews:—*e.g.*, changes of pitch due to atmospheric variations, lack of sufficient firmness to withstand blows from even small particles, the variable characteristics of the materials and the inability to preserve the adhesive properties of the glue, their high flexibility and the complications arising in their construction. To these defects the writer claims that metal airscrews are nearly exempt, adding that they may be constructed by pressing or stamping sheet metal with the various parts silver soldered, welded by the oxygen-acetylene process, electrically welded or riveted. He does not, however, make any reference to the weakness of welding or riveting when under the large centrifugal and other stresses to which an airscrew is subject.

Some calculations are given of comparative weights and strengths under centrifugal forces of steel, aluminium, and duralumin airscrews. Taking sheet chrome-vanadium steel 0.064 in. thick, aluminium 0.182 in. thick, duralumin or acieral 0.102 in. thick, he obtains factors of safety of 6-10, 3, and 7.5 respectively with weights of 52, 51, and 30 lbs., compared with a weight of 60 lbs. for a two-bladed wooden airscrew of diameter 10 feet, of blade width 1 foot, and developing 400 h.p. (V. Olhovsky, "Aerial Age Weekly," Dec. 2, 1918.)

Searchlight Arrangement on Italian Aircraft.

This article describes the arrangement used on Italian aircraft to illuminate the ground on starting and landing during night flying. Two kinds of power sources are used—first, an accumulator battery, seldom employed because of its high weight for the required capacity, and, secondly, a dynamo, sometimes in conjunction with a battery. The dynamo is either driven by a fan or connected direct to the engine, both having their advantages and disadvantages. The first is independent of the motor, but its efficiency is bad. The second is more efficient and is the one that in future will be most employed. In both cases the revolutions per minute are not constant, and therefore the voltage alters, and, accordingly, the dynamo must be fitted with a voltage regulator. Pictures are shown of both types. Diagrams of the circuits are given and explained, illustrating how the voltage is regulated by increasing or decreasing the current in the shunt winding of the motor. A description and a diagram are also given, showing the method of connection with an accumulator battery for the purpose of giving a more reliable supply of light. The voltage of the lighting system is usually about 14 volts and current 9.1 amps (125 watts). The energy, loss, etc., in various parts of the system is discussed at some length and the efficiency for a fan-driven motor system

given as 125 watts/411 watts × 100 = 30.8 per cent. The weights of the parts in this case are:—

Dynamo, together with propeller and support ...	13.5 kg.
Light reflector and lamps, etc.	6.0 ,,
Controlling apparatus and lead	2.05 ,,
Accumulator	8.0 ,,
Total	29.55 kg.

("Osterreichische Flug-Zeitschrift," Sept., 1918.)

Tacheometer for Airships and Aeroplanes.

The present instalment of this article gives an illustrated description of the Morel electric indicating tacheometer. It consists of a transmitter, taking the form of a d.c. generator, driven by suitable means from the engine shaft, and a receiver in the form of a moving coil galvanometer, this galvanometer, however, being graduated in r.p.m.

In a magnetic field, formed from a number of magnets of high alloy tungsten steel, a drum armature revolves having a commutator and a number of spring contacts for collecting the current. The magnets are so constructed as to give a constant field. The transmitter in the latest design is driven through an intermediate shaft and flexible coupling. The whole of this transmitter is contained in a casing fitted with a special dust-proof bayonet-joint cap, while the armature is driven through gearing. For airships, motor boats, etc., the transmitters are fitted with bases.

The receiver galvanometer comprises the moving coil, wound on a pressed copper frame, and fitted with spiral springs which serve at the same time as current leads from the transmitter. The movements of the coil are transmitted by teeth to a pointer fixed to the indicator spindle. ("Der Motorwagen," Dec. 10, 1918.)

"Germany First to Fly Over the Ocean?"

It is reported that at Staaken, near Berlin, an aeroplane for transatlantic flight is under construction with a wing spread of 198 feet and with engines of 3,000 h.p., and that an airship for the same purpose at Friedrichshafen has nine engines, eight propellers, and can carry a hundred passengers. The first flight, expected in July, will last forty hours. Large aeroplanes seen at Staaken had five motors each 250 h.p., and five propellers. With a span of 140 feet, they carry eight men and 2,840 lbs. of bombs, flying 14 hours at 81 miles per hour. The machines are now rapidly being converted into use for passenger and postal carrying services.

On Nov. 21, 1918, a Zeppelin with a crew of 22 and carrying 25 tons of munitions and medicines left Jamboli, in Bulgaria, and was over Khartum on the night of Nov. 22-23, when it returned. The ship is said to be capable of going from Berlin to New York and returning without a stop. ("Air Service Journal," Dec. 14, 1918.)

Warsaw-Lvov Aerial Post.

The first aerial post reached Lvov from Warsaw on Nov. 30, organised by the Lvov Defence Committee of Warsaw. The letters, which bore Polish stamps, were handed to the post office and there dealt with in the usual manner. ("Nowa Reforma," Dec. 2.)

Annular Underground Airship Hangar.

The writer describes a design of underground airship shed which was apparently placed before the German authorities, and which has up to now been subject to censorship.

A pit, as in the illustration, forming a closed circle, and gradually narrowing downwards, forms the underground hangar, the diameter, breadth across the wing, and height of which are chosen so as to leave sufficient clearance for the airship. From the plan it appears that an annular trench 40 m. across the annular portion, and of 185 m. mean diameter should be able to house eight airships, or, say, four of the rigid type 145 m. long, and four others of the non-rigid type from 90 to 100 m. long. The diameter of the annular trench could be reduced if it were desired to accommodate fewer airships.

SECTIONAL DIAGRAM OF AIRSHIP HANGAR.

In this system, the annular portion of the roof, as well as the doors of the shed, can be made to slide about the centre of the circle, so that if more than one of each type of airship is contained in the shed, it would be possible to send out the one whose longitudinal axis was not likely to be deflected by the direction of the prevailing wind. Again, it is suggested that the floor or platform should be capable of revolving also, which would further simplify matters.

Dealing with the cost of this design of shed, the writer estimates that less land would be required for the site, as it would be possible to use the roof of the underground hangar as a landing place. Charges for excavation and removal of earth would not be inordinate, as the material excavated need not be carried away, but could be used for banking up the ground inside and outside the annular pit. A thick masonry lining for the pit would be unnecessary, as the danger of collapse of the sides would be obviated by decreasing the diameter of the pit from the top downwards, since only room for the car is necessary on the floor. A thin layer of concrete should thus be sufficient as a lining. The site should, of course, be chosen so as to be free from ground water.

The roof of the shed would be of light iron construction with corrugated iron or similar framing, and small top lights. The space of roof to be covered in is comparatively small, as compared with the circular type of hangar. The sliding roof of the shed would be supported on wide diameter rollers running on a well machined roller path, driven from a motor placed diametrically opposite the shed opening and operating through teeth cut in the runway. The double sliding doors would also be driven from the same motor, by suitable means.

The shipping in and out of the airships could be carried out without difficulty. For the latter operation, it would be sufficient to post a squad of men at each side of the sliding doors in the roof. The men would gradually release the guy ropes and the airship would ascend by its own buoyancy. ("Der Motorwagen," Dec. 10, 1918.)

Loening Two-Seater Fighting Monoplane.

The Loening two-seater fighting monoplane has a 300 h.p. Simplex-Hispano engine, developing 145 m.p.h. with full military load, and climbing to 25,000 ft.

It is so simple that production is easy, as it requires only about 1/10 the usual number of parts. Rigidity and stability are satisfactory, so that it may

be said to be the first load carrying machine that can be manœuvred like the smallest single-seater. The machine weighs 1,500 lbs. and carries practically its entire weight in live load compared with the more usual 50 per cent.

The low aspect ratio (32 ft. × 7 ft.) has been found efficient. The body is deep, being built of a series of veneer bulkheads. The wings are of the usual construction. A novelty of the machine is in the arrangement of its parts, particularly in the fastening of the wings to the top longerons.

The pilot and gunner have practically no blind spot, the wing being mounted on a level with the pilot's eye.

In official trials, the monoplane carried two men, four machine-guns, and 2,000 rounds of ammunition, and climbed 10,000 ft. in 8 minutes. ("Aviation," Jan. 1, 1919.)

Production Problems in the Martin Bomber.

In view of the importance of efficient and economic production, not only have the detail parts throughout the Martin bomber been so designed as to accommodate modern production methods, but all major and minor units have been so worked out as to permit efficient and speedy progressive assembly.

All metal parts and fittings such as steel tail surfaces, motor and flight controls, are so designed as to reduce hand work to the minimum, the majority of steel plate fittings permitting their manufacture by means of blanking the forming dies.

The tool design department has designed numerous machine tool attachments (particularly assembly jigs) for production and assembly. An example is the wing rib assembly jig which enables ribs to be made complete as a separate unit. It permits not only the production of the full rib but the nose and intermediate ribs equally well. Interplane struts, longerons, etc., are made of laminations each routed on the inside; this reduces the difficulty in securing lumber of sufficient size.

The assembling of the machine requires but a very short time and no more equipment than the ordinary single-engined plane. The centre sections extending over both engines are first assembled and lined up as a unit, then the panels, which are all self-aligned, by the steel tubular struts. (L. D. Bell, "Aviation," Jan. 1, 1919.)

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